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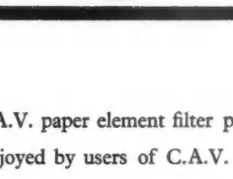

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INDEX TO "ENGINEERING"

Volume 180 now ready

The Index to Volume 180 (July-December, 1955) is now ready and will be sent to any reader, without charge and postage paid, on application being made to the Publisher, 35 and 36 Bedford-street, London, W.C.2. Any reader wishing to receive regular copies of the Index as they are published can apply to be put on the mailing list. Those already on the mailing list need not re-apply.

PLANNING FOR A GENERATION

A NUMBER of eminent people, among them Mr. Dulles, Mr. Macmillan, Dr. Erhard, have expressed themselves recently on what is called "the revival of the movement towards European political and trading unity." Some, Mr. Dulles among them, thought Dr. Adenauer's thesis for a united Europe was "unanswerable." Others, including Mr. Macmillan, felt that there was a ring of inevitability about the economic unification of western Europe and that the United Kingdom had little alternative but to participate in discussions. Thus perhaps the British restraining influence could lead to a sound workable plan which might benefit world trade, including the Commonwealth and the dollar countries. To stay out, they argue, leaves us powerless to influence and could—according to Sir Norman Kipping—"lead to a European bloc being formed against us, entailing the virtual certainty of serious damage to markets which at present represent 12 per cent. of our total exports." If other nations joined in it could take away a full quarter of our exports. If we take part, on the other hand, we might very well benefit because western Europe is one of the fastest growing markets in the world and the richest. Figures recently quoted in support of this show that the rise in internal western European trade accounted for 60 per cent. of the total increase in world trade for 1948–54.

This western European prosperity must at least in part be due to the programme of liberalisation of trade, by the gradual removal of quota restrictions on imports, which was started by the Organisation for European Economic Co-operation. Together with the creation of the European Payments Union this cleared the way for what Mr. Macmillan described as "the great expansion of trade within Europe which has taken place in the last seven years." Now all the quotas have been removed except a hard core and the nations concerned have been considering how the process of closer economic association could be taken further. Another movement which has paralleled the removals of quotas, has been towards economic integration through the setting up of the European Coal and Steel Community. Six countries—Belgium, France, Germany, Italy Luxembourg and the Netherlands—agreed to place their coal, iron and steel industries under the management of a High Authority, or supranational body, responsible to a European political assembly and not to the governments of the countries concerned. There have been suggestions that several other industries could be brought in from time to time.

The Governments of the same countries have often discussed some form of customs union or common market. Last July, the Ministerial Council of O.E.E.C., with Mr. Macmillan in the chair, set up a working party to consider how this might be achieved and how other O.E.E.C. countries could take part. At a meeting on September 24, the working party were instructed to explore the possibility of creating a "free trade area" which would include both the Customs Union and the other O.E.E.C. countries including Britain. The conditions of tariff reductions would not be affected—by the early 1970's no tariffs would remain except on agricultural products, but the countries outside the Customs Union of the six would be free to preserve their own tariffs against other countries outside the area. If western Europe, including the United Kingdom, joined in a free trade area this would constitute a common market of nearly 250 million people. In his outline of the scheme Mr. Macmillan described the benefits to this country as the provision of "the full-scale advantages of large-scale production which tend in the modern world to be associated with big economic units, such as the United States and now the U.S.S.R." If this group grew prosperous, he argues, the advantages to the Commonwealth would be "as a market and as a source of capital. For it is the large units which can accumulate and export capital."

The idea will attract many, for it is bold, imaginative and offers western Europe an opportunity of forging ahead and overcoming national differences quicker than had seemed conceivable only a few years before. The opposition—and there will be fierce opposition when the matter is discussed with industry—will come from industrial groups which have no wish to find themselves faced with unfettered German competition even if they have 10 to 15 years to get themselves ready for it. There are other objections. Sir Ernest W. Goodale, writing on behalf of textile users, considers a free trade zone as a "virtual reversal of the policy adopted in 1932 for the protection of British productive industry." It was an irrevocable step to take, which could ruin many industries. Another objection is that the wage levels in all countries are uneven and that no industry can be expected to compete against cheaper labour. Politically it might—if the United States defaulted—leave Britain helpless in the clutches of Europe.

Such criticisms and objections abound. All centre round the same basic theme: protection for our manufacturing industries. Mr. Macmillan answered that we depend upon international trade for our livelihood,

and that we cannot maintain full employment in the long run unless we have ample foreign markets. Some industries would suffer—not least motor vehicles—but others would benefit, and among them a large proportion of metal using industries, benefiting as they do from cheaper British steel. The alternative is to abandon Western Europe to German and later to Soviet economic domination.

* * *

Plain Words

One of Her Majesty's Ministers provides some ready-made "plain words" this week. Mr. Aubrey Jones, Minister of Fuel and Power, had this to say at the opening of the Fuel Efficiency Exhibition last week:—

"We could still achieve a substantial saving by the better use of fuel—a vital saving in the light of our precarious economic situation. How do I achieve this saving? . . . Well, I employ the only language which the detractors of industry tell me that industry understands—I address myself to your pockets. I provide you with quite handsome bonuses if you will proceed to use fuel a little more economically—the loan scheme and the investment allowance. And I can make it extremely expensive for you if you don't. There is still plenty of room, you know, for a further increase in the price of coal. After all we are still importing it at £3 to £3 10*s.* dearer than it is at home. If I did a dirty trick like that you would, of course, scream to high heaven. But as a matter of fact British industry is on weak ground in protesting about increases in the price of coal when I'm told that at least 10 million tons a year could be saved with more efficient use. Now if you were to reach a stage where coal was most economically used and I were then to raise the price by £3 a ton—well then you would have every justification in complaining."

Where was it that we last heard this kind of approach to our negligent, selfish selves? There is something vaguely familiar about it. At school, surely. When the little sneak who wouldn't own up to his misdeed was going the right way to have us all kept in after school hours. This mixture of controls and freedom seems to be working well in post-war Britain, but Government ministers must be discouraged from thinking that they are directly responsible for achieving results. It is their job to create the right climate and leave industry to do the rest. There is so much work to be done in industry and there are so few trained and competent men to do it that wise managements are careful in their choice of priorities. Another £3 on the price of coal would certainly lead to more attention being given to fuel economy, but it would inevitably cause the neglect of other, perhaps more important, considerations. The Government would have no need to juggle with coal prices if they used their powers to correct the fundamental weakness: there are still 45 per cent. of university undergraduates reading Arts. That figure ought to be halved within the next few years.

OCEAN RESEARCH SHIPS

EQUIPMENT IN SOME CONTEMPORARY BRITISH VESSELS

In this article we propose to describe some of the more important British ships engaged in oceanographic research—the study of the physics, biology and geology of the sea and its bed, upon which the more effective exploitation of the ocean's resources—possibly as important for mankind's future as the peaceful application of atomic energy—must depend. Some of these ships are primarily used for fundamental research, while others are carrying out investigations of immediate value to the fisheries.

THE "DISCOVERY II"

In the famous Royal Research Ship Discovery II, the National Institute of Oceanography have, probably, one of the largest and most useful floating research stations that has yet been built. The Discovery II, it may be recalled, was constructed for the Discovery Committee by Ferguson Brothers (Port Glasgow), Limited, and was launched on November 2, 1929, since when she has steamed some 500,000 miles and has twice circumnavigated the Antarctic continent in mid-winter. Primarily intended for whaling and oceanographic research in the Antarctic seas, she was designed for reliability and self-sufficiency under the most rigorous conditions, and these features have proved invaluable assets in the varied investigations that she is now called upon to perform. Thus, ample spares are carried and it is possible to carry out repairs on equipment and instruments—or to improvise new ones—in the engine-room workshop, which is usefully equipped with two lathes, a high-speed sensitive drill, a shaping machine and a grinding wheel; in the small scientific workshop which has its own precision lathe; and in the net room which is fitted with a sewing machine and a hydraulic wire-rope splicer, and in which the stocks of fine-mesh silk for plankton nets are housed.

R.R.S. Discovery II has a registered gross tonnage of 1,063 tons, and is 234 ft. long overall with a moulded breadth and depth of 36 ft. and 20 ft. respectively. She has a maximum speed of 13½ knots and an economical speed of about 9 knots. With an oil-bunker capacity of 316 tons, carried amidships, she is capable of a maximum range of about 10,000 miles. She retains steerage way down to very low speeds, a most valuable characteristic for oceanographic work.

To protect the ship in pack ice, the hull was designed to be extremely robust with double plating over the forward part and along the water line, and strong reinforcement in the forehold. Her propulsion machinery comprises a single-screw triple-expansion steam set developing 1,250 h.p. at 128 r.p.m., specially designed for Antarctic service, with ample reserve strength. Her two boilers, operating at 200 lb. per sq. in. with a total heating surface of 3,550 sq. ft., are oil-fired using the Wallsend-Howden forced-draught system.

All the pumps, generating sets and deck machinery are steam-driven by auxiliary engines discharging into the main condenser. Of the two independent main generating sets, one is the original 28 kW 110 volt Sisson set; the other, installed in 1954, is a 30 kW set supplied by the Sunderland Forge and Engineering Company. For emergency use there is a 15 kW set, driven by a Perkins Diesel engine. Alternating current for the ship's radio and navigational equipment is provided by individual rotary converters; for laboratory use—and wired into all laboratories—there is a second supply from a 6 kW rotary converter, fitted in the engine room.

Since the Discovery II was taken over by the National Institute of Oceanography in 1950, the lower deck has been completely re-equipped, and the entire complement of 52—including six scientific staff—are now accommodated in cabins. The laboratory space has also been increased by an additional rough laboratory in the forecastle.

Discovery II is well equipped with modern radio and navigational aids and sounding equipment. The main radio is a Marconi "Worldspan" installation, and she has a radio telephone, direction-finding equipment, "Loran," and a Decca Navigator set. Speed and distance are recorded by means of a Chernikeeff log. Two Kelvin Hughes recording echo sounders are fitted: Type 21B for ordinary navigational use and Type 21E for deep soundings. Alternative to the 21E recorder is a Type 26E recorder, using the "Teledeltos" method of recording on metallised paper. An improvement in the directional quality of the deep echo sounder has been made by stabilising the transmitter and receiver to overcome the effects of rolling. This has been done by mounting the reflectors so that they can swing freely in the athwartships line.

The deck equipment for scientific work includes a main winch carrying 5,000 fathoms of tapered wire rope and 1,200 fathoms of trawl warp, at the aft end of the upper deck; a deep hydrographic reel (with 3,500 fathoms of 4 mm. wire) and davit on the forecastle, and two hydrographic reels, one with 3,500 fathoms of 4 mm. wire, and a smaller reel with 700 fathoms on the port side of the deck. The davits are equipped with spring-type accumulators to relieve shock loads on the cables. All deck machines are provided with metre sheaves recording the length of cable paid out. Stowed on the aft starboard side of the deck is a core tube for taking ocean-bottom samples.

One of the two main laboratories, which are situated on the upper deck amidships, is fitted with a weighted gimbal-mounted table which remains effectively stable when the ship is rolling and pitching in heavy seas. A small forward laboratory in the forecastle, close to the deep

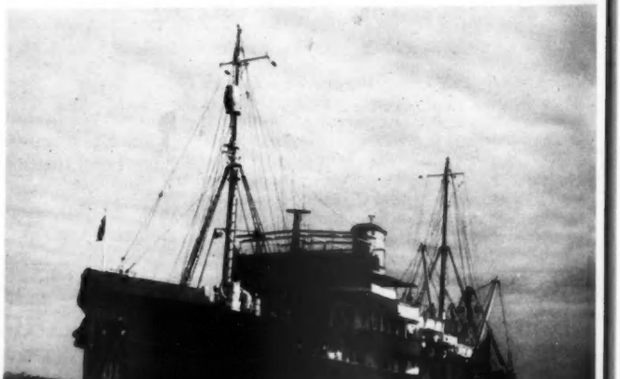

Fig. 1 R.R.S. "Discovery II," famous for her Antarctic voyages between 1929 and 1939, is now operated by the National Institute of Oceanography mainly in the North Atlantic. She will play an important part in the International Geophysical Year programme.

hydrographic reel, houses the reversing water bottles used for recording deep-water temperatures and taking samples for salinity determination. It is, incidentally, interesting to learn that the contamination of the samples by corrosive action in the bottles has been largely overcome since a nylon lining has been adopted in place of protective plating; the nylon coating is applied during manufacture of the bottles.

Another small laboratory on the main deck is at present fitted with the recording instruments for the ship-borne wave recorder, the mechanism of which is installed in the boiler room. This is one of the newer tools of oceanographic research developed by the Institute; a

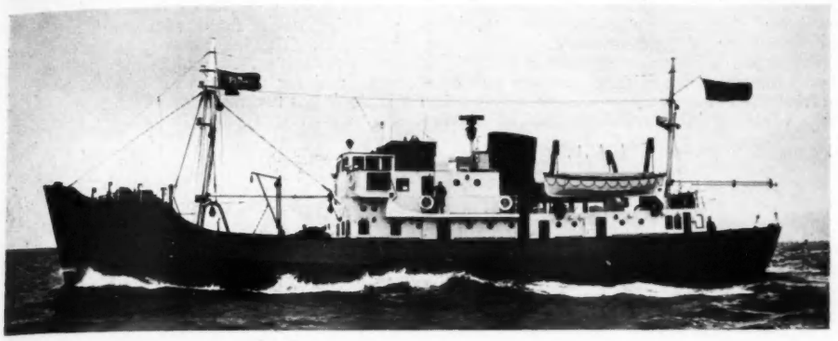

Fig. 2 The Marine Biological Association operate R.V. "Sarsia" mainly around the south-western coast of Britain, collecting hydrological and sea-bottom samples and living organisms.

description of some of these interesting techniques has been given in "Instruments for Ocean Research" in ENGINEERING for May 25, 1956 (page 398). Also on the main deck are a photographic room and a dark room. Scientific instruments are housed in the scientific workshop, and spare research equipment of the heavier type is stowed in the aft hold.

As a result of the Discovery II's Antarctic voyages for the Discovery Committee between 1929 and 1939, and her most recent Antarctic voyage for the National Institute of Oceanography in 1950–1951, it is generally agreed that more is known about the chemical and physical condition of the Antarctic waters, and the plant and animal life they support, than those of any other ocean. To-day, Discovery II is mainly working in the North Atlantic, on studies of waves and deep-water currents, developing new methods for studying productivity, catching deep-sea animals and investigating the ocean floor. She has also been chartered to the Admiralty for special research duties and has served as a weather ship.

Discovery II has an important part to play in the International Geophysical Year in studying the general circulation of water in the ocean; she will take temperature measurements, water samples and current measurements at a range of depths, down to the bottom, along certain critical ocean traverses. She will also collaborate with ships from the United States, and possibly from U.S.S.R., and with a new ship now being built in Norway, in a detailed examination of the deep-water movements in a small area in the mid-Atlantic. Methods similar to that using neutrally buoyant floats, as described in the May 25, 1956, issue of ENGINEERING, will be used.

R.V. "SARSIA"

Also concerned with fundamental research, the Marine Biological Association's recently-built vessel Sarsia is designed for rather different duties. The Marine Biological Association is concerned, basically, with the productivity of the sea in all its variations, and with the life histories and habits of marine animals. Their activities are mainly concentrated on the South-Western coast of the British Isles, collecting their material—hydrological observations, bottom samples, and living organisms caught in the trawl and plankton nets—during short voyages, with occasional cruises to distant and deeper waters. The Sarsia, a modern ship, was designed specially for this work by Graham and Woolnough, Liverpool, and was constructed by Philip and Son, Limited, Dartmouth. She was launched in 1953.

Because much of her trawling and dredging work is carried out near the shore, the Sarsia is a much smaller vessel than the Discovery II, and Diesel propulsion has been adopted. Her registered tonnage is 319 tons and she is 128 ft. long overall, with a moulded breadth of 28 ft., a moulded depth of 13 ft., and a mean load draught of 8 ft. 6 in. Her design speed is

Fig. 3 The "Ernest Holt" is used by the Fisheries Laboratory of the Ministry of Agriculture, Fisheries and Food in the cod-fishing grounds of the Arctic Ocean.

10 knots, and economical speed 8½ knots at 125 shaft r.p.m., at which the fuel consumption is 1 ton in 24 hours. Her range is just over 4,000 miles.

The main propulsion engine is a vertical four-stroke single-acting National R4 AUM6 Diesel engine equipped with a Napier turboblower, and developing 290 b.h.p. at 486 r.p.m., driving the propeller through S.L.M. reverse-reduction gearing. To provide the low speeds necessary for scientific work, there is a completely independent low-speed drive comprising a 20 h.p. variable-speed electric motor geared to the propeller shaft through the main gearbox; it cannot be engaged until the main engine is disengaged.

The main propulsion engine drives two lubricating oil pumps, one salt-water and one fresh-water pump; additional water, bilge and general service pumps are electrically driven. There are two independent Diesel-driven direct-current generators, developing 60 kW and 35 kW respectively; the auxiliary engine driving the larger set also drives the electro-hydraulic unit operating the main trawl winch. Two hydrographic winches, as well as the trawl winch, are hydraulically operated by V.S G. units; the windlass is electrically driven. Other auxiliaries include two Diesel-driven air compressors (one of these is driven by the engine of the smaller generator set) and a single-phase 50 cycle alternator giving a stabilised 220 volt supply, but which can also be hand-regulated between 100 and 220 volts.

Navigational equipment includes a Decca Radar unit, a Marconi Graphette echo-sounder, and Decca Navigator equipment. Two Kelvin-Hughes recording echo sounders are provided, one recording 0 to 720 ft. or fathoms, and the other 0 to 2,250 fathoms.

The main trawl winch, situated forward of the deck-house on the main deck, has three drums, the port drum carrying 1,800 fathoms of 1⅛ in. wire and the centre and starboard drums with 500 fathoms of 2½ in. wire; a total pull of 3½ tons at a speed of 150 ft. per minute is provided. The trawls are handled from the starboard side of the deck, which is kept clear, and the catch is kept alive in closed water tanks on the port side of the deck which are continuously fed from spray pipes with sea water.

The main hydrographic winch, completely enclosed and situated in the forecastle, has a single drum carrying 5,000 m. of 4 mm. wire, and has an average hauling speed of 200 m. per minute with a 300 lb. load. A "Discovery" type hydrographic davit is on the port side of the fore deck. The aft hydrographic winch, on the boat deck aft of the main mast, has two drums, one carrying 500 m. of 4 mm. wire and the other carrying 300 m. of 7 mm. wire. The main mast carries a light derrick with a sliding boom enabling light gear to be operated over the stern or quarter.

Laboratory accommodation comprises a main laboratory at the forward end of the deckhouse, equipped with a "Discovery" type gimbal-mounted table with a small aquarium tank, and with post-office type racks for taking experimental set-ups that can be built up in the shore laboratory and assembled in position as desired. The racks permit easy access to any part of the assembly. Another arrangement to expedite work and avoid cluttering up the laboratory floor is the use of a removable drawer unit for collecting boxes of specimen jars in each work bench; the entire drawer can be removed and stored in a general store on the lower deck. Aft of the main laboratory is an accumulator room with two banks of accumulators each of 100 amp.-hour capacity, from which the laboratory can be fed with any voltage up to 36 volts in 2 volt steps. Alternating current is also available for electronic instruments. There is a smaller laboratory at the aft end of the deckhouse, with an adjoining dark room. In addition to the lower deck general store, which also serves as a work-room, there is a scientific store in the forecastle housing collecting jars, nets, dredges, trawls, etc.

Living accommodation for four scientists, three ship's officers, two engineers and 16 crew, is on the lower deck; here also are three cold rooms, one for domestic and two for scientific use.

Much of the Sarsia's time is spent in trawling for living specimens which the M.B.A. supplies for teaching purposes to universities and schools, in addition to supplying the shore laboratory at Plymouth; trawling is carried out by the ship's crew. Among the scientific work that is being undertaken may be mentioned physiological investigations on the changes of muscle opacity in the live squid resulting from muscle stimuli by electrical impulses: a photocell is used to detect the changes in opacity, a delicate electro-mechanical transducer records the muscle tension, and a sensitive thermopile measures the change in muscle enery, and the three simultaneous records are obtained on a cathode-ray oscillograph.

"ERNEST HOLT"

The remaining two ships with which this article is concerned are both fisheries research

vessels, whose investigations of the ways of life of the fish population and its relation to temperature, salt content, and plankton distribution, serve to direct the trawling fleets of England and Scotland to more fishful waters.

In 1949 the Fisheries Laboratory of the Ministry of Agriculture, Fisheries and Food at Lowestoft commissioned the research trawler Ernest Holt, for work in the Arctic Ocean, where cod-fishing grounds abound. Built for the Ministry by Cochrane and Sons, Selby, Yorkshire, the design was based upon one of the most popular arctic trawlers in service. She is an extremely stable and well-heated ship, so that the rigours of arctic life on the sea are minimised as far as possible—essential for efficiency as well as for comfort.

With a gross tonnage of 600 tons, the Ernest Holt has a length between perpendiculars of 175 ft., a moulded breadth of 30 ft. and a moulded depth of 16 ft. Her cruising speed is 11 knots, and generally she cruises for an average duration of 29 days in the Barents Sea, in the regions of Bear Island and Hope Island throughout the year. She carries a complement of 31, including four scientists.

To withstand navigating through ice, the hull plating is strengthened at the bow and stern and along the waterline and is reinforced by stringers in the forehold.

The main propulsion machinery comprises a 900 i.h.p. triple-expansion steam engine by Amos and Smith, Hull, supplied from an oil-fired Scotch boiler. The oil bunkers have a capacity of 210 tons; there are two separate Weir feed pumps and an air pump.

The main electrical supply is by a 15 kW and a 25 kW generator driven by auxiliary steam engines, and a third steam-driven 25 kW generator supplies 400 volt alternating current to a submerged pump. A Diesel generator set is provided for harbour use.

Navigational and wireless equipment includes a Brown gyro repeater steering compass; two Kelvin Hughes MS21b echo sounders; a Chernikeeff electric log; Marconi Oceanspan wireless telegraphy set, radio-telephone and direction-finding sets.

The main laboratory and accommodation for scientists are situated below decks, in the space that on a normal trawler would constitute the fish room. In the Ernest Holt, the brine-cooled fish room is small and, together with a pilot quick-freezing plant and low-temperature store (— 10 deg. C.), and the associated compressors and circulating pumps, occupies a space of 1,500 cub. ft. Five positions are provided in the main laboratory, which is provided with hot and cold, fresh and salt-water supplies, and stowage for some 1,200 samples in sliding trays, adjacent to a lift which communicates with two small deck laboratories where the incoming samples receive a preliminary sorting.

The deck laboratories, which are immediately aft of the main trawl winch, have intercommunication with the hydrographic winch platform on the forward end of the engine room casing. The hydrographic winch, driven by a 2 h.p. electric motor, is equipped with 500 fathoms of $\frac{1}{16}$ in. wire, and sliding booms are provided to carry the wire clear of the ship's structure and the screw. The steam-driven trawl winch, in addition to 1,200 fathoms of $2\frac{3}{4}$ in. trawl warp, carries an additional central barrel with two 600 fathom coils of light wire, used in conjunction with derrick booms below the wheelhouse, for towing nets and lowering a grab.

Perhaps one of the most interesting activities of the Fisheries scientists on Ernest Holt is their recent attempt to predict the haul, in rough quantitative terms, from fish echoes on the cathode-ray tube of the echo-fishing equipment.* In experiments carried out last year they had a promising degree of success in forecasting the catch of cod and haddock (but not in distinguishing between these types), by relating the number of baskets per hour's tow to the echo strength and the depth; the length of the fish was also found to affect the accuracy of the result. To carry out this work, two operators were necessary in order to watch the tube continuously and to time the period over which echoes of a given size appeared on the screen.

* New Echo-Sounding Methods at Bear Island, *World Fishing*, October 1955.

F.R.S. "EXPLORER"

Most modern of the vessels reviewed here is the Explorer, of the Scottish Home Department's Marine Laboratory in Torry, Aberdeen, which went into operation on April 13 this year. Like the Ernest Holt, her job is to sample fish stocks and collect data on fish populations and environments; she will be operating mainly in in the North Atlantic as far afield as Greenland. One of the prime considerations in the design of Explorer has been stability. She therefore carries plenty of bottom weight which, when fully loaded, makes her somewhat lively in a beam sea. As fuel is used and the centre of gravity rises, she becomes a most comfortable ship while retaining excellent stability characteristics. Somewhat larger than the Ernest Holt, F.R.S. Explorer has a gross tonnage of 862 tons, is 183 ft. 6 in. long between perpendiculars, and 32 ft. in breadth. With an oil bunker capacity of 284 tons and a fresh-water capacity of 110 tons, she has an endurance of over 8,000 miles. She carries a crew of 28 and a scientific staff of seven, which can be increased to ten. The accommodation is exceptionally spacious with two-berth cabins for the crew and separate crew's recreation and mess rooms; the officers and scientists are normally accommodated in single-berth cabins, with provision for "doubling up" if necessary. A roomy saloon provides seating for 16 officers. All the accommodation is mechanically ventilated and heated by hot water radiators.

One of the interesting features of Explorer is the extent to which aluminium has been used in her construction, in the deckpounds and bridge deckhouse, and in the fish rooms, which are aluminium-lined and have aluminium fittings. Her hull is reinforced for navigating through ice. Her two lifeboats also are in aluminium, one of them being equipped with a marine Diesel engine.

Explorer, also, has a triple-expansion steam engine, developing 1,000 b.h.p. at 120 r.p.m. and supplied by a forced-draught oil-fired Scotch boiler. All her auxiliaries, however, are electrically driven, direct-current electric power at 220 volts being supplied by two 80 kW and one 24 kW Diesel generators. In the event of power failure, emergency lighting supplied by batteries comes into operation automatically. For scientific use, single-phase alternating current at 230 volts is supplied by one 50 kVA and one 10 kVA alternator.

Among her navigational aids are three types of Kelvin Hughes echo sounder, one of which is capable of sounding to 4,500 fathoms; a submerged log and revometer; and a projection-type compass on the wheelhouse top. She is provided with electric-hydraulic steering gear which can be controlled by power or by hand, both from the wheelhouse and from the steering compartment.

Trawling is carried out from the starboard side of the ship, which has heavy gallows frames and sheaves to cope with the largest size of trawling gear. Hydrographic work is carried out from the port side. The steam-operated trawl winch carries 1,250 fathoms of trawl warp, and a centre drum for survey work. There are three hydrographic winches—a steam-operated winch of 1,500 fathoms capacity at the aft end of the boat deck, used with port and starboard davits for operating various types of net (for sampling plankton) through special measuring gear; and two 5,000 m. electrically-driven winches operated in conjunction with Kemp shock-absorbing davits fitted with depth and speed indicators. The laboratories, in the deckhouse below the bridge, are equipped for hydrographic work and for dealing with fish and plankton. Explorer has two refrigerated fish rooms operating at 30 deg. F. and 10 deg. F. respectively.

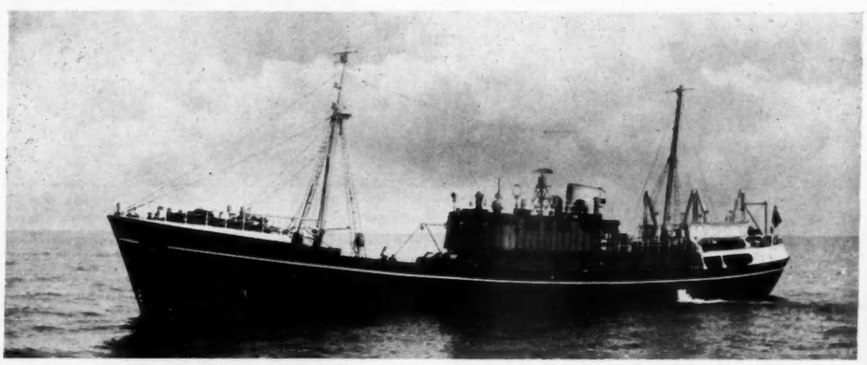

Fig. 4 Also concerned with fisheries research is the "Explorer" of the Scottish Home Department's Marine Laboratory at Aberdeen. She samples fish stocks and collects data on fish populations and environment in the North Atlantic.

Hot and cold, fresh and salt-water services throughout the ship are supplied by two separate pressure systems fitted in the stokehold.

In addition to their standard sampling and hydrological work, the Aberdeen Marine Laboratory are carrying out a number of interesting investigations, including the automatic photography of the sea bottom at depths down to 150 fathoms and underwater cinematography, by frogmen, of the action of trawl and plankton nets. One of their most interesting projects is the investigation of the noises made by fishes, the ultimate objective being the identification of shoals located by echo sounding. A hydrophone, comprising a crystal microphone and a pre-amplifier, is lowered on an armoured cable which serves both to carry the power supply to the amplifier and to convey the received sound up to the control unit and amplifier on the deck. Further amplified, the signals are recorded on a magnetic tape recorder and are also transmitted audibly on a loudspeaker.

This project is still in the initial stages, and the difficulties in separating the very small noise generated by living organisms from the high background noise of the water motion and the ship's machinery have not yet been satisfactorily overcome. In the United States, we understand, some 250 types of fish and other organisms have been identified by similar acoustic equipment in tank experiments.

It is perhaps interesting to note, in conclusion, that oceanographic and fisheries research, which are primarily directed to productive and peaceful ends, are strictly budgeted and receive only limited financial support for the purchase of research equipment. Thus, much of the expensive apparatus that is commonplace in official research establishments devoted to military ends is out of their reach, and the oceanographic scientist is developing considerable ingenuity in the construction of complex instruments from war-surplus equipment and the like.

Weekly Survey

Cover Picture: *Many resistances which require windings of comparatively large section are made from strip material. For the sake of compactness and convenience the strip is wound edgewise, as shown in the illustration.*

* * *

Oil Route Tangles

There is a world of difference between the various grand schemes which have been aired in the last few weeks for transporting Middle East oil without going through the Suez Canal and what is likely to be immediately practical. The ideal answer to the Suez *impasse* to many people is to build bigger and faster tankers to go round the Cape or to build new pipelines through the more friendly Arab states from Mesopotamia and the Persian Gulf to the Levant coast. The problem of building quickly a sizeable fleet of super tankers of 60,000 and 100,000 tons apiece on top of the ambitious building programme already in hand with the world's shipbuilding yards is quite apparent. Last week, the first moves of the Iraq Petroleum Company to persuade the Lebanon to adopt a more reasonable attitude on oil taxation so far as the company's line from Kirkuk to Tripoli is concerned—and, additionally, building a new 24 in. by-pass pipe to the Syrian port of Banias—received a quick setback. The Syrian Government has let it be known that it will not pursue an oil policy which will be to the detriment of any other Arab country.

Meanwhile the United States Government has put back into commission six T-2 type tankers which could serve as additional tonnage for the Cape route. These tankers, which are in addition to a further 17 re-activated to supply petroleum to military installations, are each just under 17,000 tons with a speed of 14·5 knots. This is the widow's mite with a vengeance, but it is at least a practical gesture. During the next few months it is clearly going to be difficult to steer a practical middle course, so far as the transportation side of the Suez crisis is concerned, between grandiose and somewhat sweeping long-term solutions and humble, unimpressive short-term measures to keep the pipelines, literally and metaphorically, adequately stocked.

* * *

Petroleum Pattern for the 1960's

The Oil Committee of the Organisation for European Economic Co-operation has just published a report on the prospective demand for oil products in Western Europe by 1960. It puts the total demand for that year at 153 million tons, compared with 100 million tons in 1955. It goes on to say that the likely demand by 1975 is of the order of 340 million tons. These figures are not new and serve only to confirm estimates made by the oil companies, whose figures, of course, were the main source of the O.E.E.C. forecast. The report, however, makes an interesting estimate of the pattern of demand for different kinds of oil products over the period reviewed. The big change expected by 1960 is the particularly large increase in fuel oil compared with a much slower rate of increase of demand for gasolines and middle distillates. By 1975 the emphasis on fuel oil is expected to be even greater, but the committee does not put a figure to it. The demand for fuel oil is, of course, to some extent one for a blend of residual and distillate fuels and the report prefers to go no further than forecast a big gain in the middle distillates and fuel oil compared with gasolines.

When the Commission for Energy, another O.E.E.C. committee, reported on the need for additional energy for Western Europe in May, 1956, it estimated that 7,000 million dols. would be required by 1975 to meet the investment requirements of new oil capacity. If the estimates of demand and of capital investment are anywhere near the right dimension, the trend of both sets of figures gives some idea of the strain which could be put on Western Europe's resources if crude oil does not come through the Suez Canal and if a larger proportion of it is to come from the western hemisphere. These figures were calculated before the Suez crisis occurred and no account is therefore made for increased reliance on long-distance tanker hauls and high-cost oil wells in America. The whole energy picture for Western Europe is thus exceedingly complex and might be very misleading. The prospect for 1975 may yet be seriously modified by the capital cost and individual production costs of coal, oil and atomic energy as they develop in relation to one another.

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Oxygen Company Stresses Research

A new private company, known as British Oxygen Research and Development Limited, or simply as BORAD, has been registered as a subsidiary concern of the British Oxygen Group of Companies, and came into existence on October 1. The new company has been formed because research and development is regarded by the parent board as a separate activity equal in status and importance to the operating companies in the Group.

BORAD has taken over the British Oxygen research and development centre at Morden, Surrey, which has been in operation for over ten years and, in addition to its programme of work for the group, the organisation is being increasingly called upon to undertake work for outside bodies, including Government departments. The formation of the new company conforms to the parent firm's policy of constituting the principal sections of its business, other than head-office departments, into separate organisations. Thus, two new operating subsidiary companies, known as British Oxygen Gases Limited, and British Oxygen Chemicals Limited, were formed in October last year.

The board of the new company comprises the chairman, Dr. P. H. Sykes, who was appointed general manager, research and development, in 1948, and elected to the board of the parent company in 1953; Dr. Norman Booth, the managing director, who was made general manager, research and development, in 1953; and Dr. L. C. Bannister, who was promoted to be assistant manager, research and development, in 1954. The five principal departments of the new company are: basic research, chemical products, gas applications, gas separation, and engineering. Their work includes studies on the production and handling of a range of industrial gases, in gaseous or liquefied form; the separation of rare gases; inert-gas shielding in welding and cutting processes; flame enrichment with oxygen in open-hearth steel furnaces; and the manufacture of special chemical products. The organisation employs about 400 persons and apparently has encountered little difficulty in recruiting and retaining as heads of departments and research principals some 100 keen and active young qualified scientists and technologists.

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Rootes and Air Conditioning

The announcement last week that Rootes Motors, Limited, have acquired a controlling interest in Tempair (Dorking), Limited, is reported to be the first step taken by the company in diversifying their interests outside the motor industry, apart, of course, from their activities during the war years. In this country—except in certain special industries including the textile industries, tobacco, confectionery and some chemical industries—air conditioning still tends to be regarded as a luxury rather than a necessity. It is very difficult to obtain figures for the turnover of the industry, since in most contracts the specific air-conditioning equipment constitutes only a small proportion of the total value of the contract. It has, however, been estimated that total home sales of air-conditioning equipment, including fans and equipment to control humidity and temperature, amount to about £5 million per annum.

In 1955 imports of air-conditioning machines and refrigerating machinery, excluding electrically operated refrigerators of a storage capacity not exceeding 12 cub. ft., amounted to about £$\frac{3}{4}$ million, about three times the corresponding figure for 1953. This rise gives a measure of the growing interest in air conditioning in this country and it is understood that most companies in the industry now have substantial order books.

Many British companies also have important contracts abroad, but here again exports of air-conditioning equipment represent only a small part of the total value of foreign contracts. In 1955, exports of air-conditioning machines comprising elements for cooling, control of humidity, cleaning and circulation of air amounted to £336,000 and exports of mechanical or electrical fans other than desk or ceiling fans to £1·4 million. Some important contracts have been obtained for air-conditioning offices and laboratories of oil companies in the Middle East. Another notable achievement by the industry has been the completion of 6 million dols. contract for air conditioning the General Motors technical centre in Detroit.

It seems improbable that the entry of a motor-vehicle producer into the air-conditioning field presages any intention to introduce air-conditioning units for motor vehicles in this country. In the United States, however, sales of auto air conditioners, incorporating a small refrigerating unit driven from the engine of the car, have increased very rapidly since their introduction in 1953, and their use is by no means confined to the warmer States of the south and south-west. In 1955, 176,000 new cars in the United States were air conditioned and it was predicted that this figure would increase by about 50 per cent. a year for the next five years.

* * *

Scotland and the Credit Squeeze

Scotland has for long lamented the comparatively small stake which it has in motor vehicles, especially in private cars, and in consumer durable goods. Occasionally, this lack of diversification of industry has its advantages, and such is the case at the moment. During the first six months of 1956, industrial production in Scotland was 2 per cent. higher than in the same period of 1955 according to the *Digest of Scottish Statistics*. This is very little different from the general modest improvement in industrial production for Britain as a whole, but it is very likely that the experience of Scotland since the end of June has been much more favourable than that of England. It may be noted that the slow rate of industrial expansion in Scotland in the first half of this year was due to quite different factors from those which have mainly influenced the trend of output in England. In Scotland, the slight decline in coal output over the period has had an important effect on the figures and so has a mild drop in engineering and shipbuilding, this last being probably largely fortuitous since the shipbuilding industry and the heavy engineering industry are both on the whole exceedingly prosperous.

Thus while England is now faced with the consequences of a serious drop in motor-car production and the continuing depression in consumer durable goods such as domestic appliances, Scotland remains geared to the trend of production in the heavy industries. There are signs that there has been a cut-back in the output of precision instruments, but even at two points where some weakness might be expected to

develop, such as commercial vehicles and office machinery, output is still at a high level. It would seem that if Scotland is to suffer from the credit squeeze to anything like the same degree as England in the next few months, it will come through the volume of new industrial building. If that should fall, Scotland will feel the pinch; otherwise, Scottish industry can look with some confidence at the recent buoyant trend in tramp freight rates, the shipbuilding implications of the Suez crisis and the Government's general policy of stimulating heavy industries, leaving the English to view with apprehension the trend of car sales, radio and television sets in the home market.

* * *

Taxation of Employees of Foreign Firms in Italy

Italy is an attractive market for many kinds of British goods, one example being agricultural machinery, as was made evident in Weekly Survey of September 21, page 359. Many British firms would like to know more about conditions in Italy and perhaps to open an office there, but one of the factors to consider before doing so is the level of taxation their representatives would have to pay.

Broadly speaking, there are three direct taxes which foreign residents, in company with the Italians themselves, must pay. The first is the Ricchezza Mobile tax on income from investment, business transactions or wages. This tax is payable on March 31 each year for the previous calendar year. It is deducted at source from wages and salaries, and firms have to make their own arrangements for a refund from their employees. Incomes up to 240,000 lire (about £130) are tax free. From 240,000 lire to 960,000 lire (£520) tax is levied at 4·4 per cent. and at 8·8 per cent. on all earnings above this level. Family allowances and cost-of-living allowances are exempt.

The second direct tax is the progressive complementary tax. This is an additional income tax payable on all income from work in Italy and on the proceeds of any income, from abroad, spent in Italy. All the reliefs given for the Ricchezza Mobile tax apply, together with allowances for life-insurance premiums paid to foreign companies, interest on loans, and amounts paid in other direct taxes. This tax is also deducted at source at the rate of 1·65 per cent. of all earnings above 540,000 lire (£305).

The third tax, the Family Tax, differs from the other two in being paid to the Municipality instead of the Government. It is based on the total income of the whole family. After deducting the dependant's allowances and subsistence allowance (fixed at 360,000 lire a year in Rome), tax is levied at rates from 2 per cent. to 12 per cent. on incomes from 200,000 lire to 12 million lire.

Although the employee of foreigners working in Italy must pay three direct taxes, he is much better off than his colleagues at home. Rates of taxation are low and although the regulations sound " fierce," the Italian bureaucracy is notoriously slow moving. Summing up, therefore, the level of taxation on their employees' earnings is not a factor which should stop British firms opening up branches in offices in Italy.

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Britain's Best European Customer—Holland

For the past two years the Netherlands have been Britain's biggest export market in Europe. The value of exports to Holland has increased from nearly £50 million in the first six months of 1954, to over £57 million in the corresponding period this year. Since overcoming the difficulties of the years immediately after the war, the Dutch economy has rapidly expanded, and as a member of the Benelux union, Holland is part of a common market of over 20 million people. A very low common tariff and the removal of quantitative import restrictions under the O.E.E.C. liberalisation policy mean that there are no formal obstacles to the expansion of Anglo-Dutch trade.

Dutch imports from Britain reflect the growing industrialisation of the country. To-day only 20 per cent. of the working population are in agriculture, while 53 per cent. are in industry and commerce. As climate and occupations are broadly the same as in Britain, practically anything made in Britain, except perhaps cricket bats, has a market in Holland. Apart from consumer and household goods the principal export possibilities are for semi-manufactured goods, such as metal alloys, steel goods, plastics and chemicals. The Dutch are also interested in internal-combustion engines, electrical machinery, excavating and earth-moving equipment, industrial control gear and technical instruments. Atomic-energy equipment represents a new and promising range of exports. British motor cars, which dominated the market immediately after the war, have now been replaced by German cars, but American and French cars are also gaining ground.

Although Britain is exporting more goods to the Netherlands, the British share of the market is actually falling. The shares of Belgium, West Germany and the United States, on the other hand, are all increasing. In a market as open as this, competition is not only in price and style, but also in delivery dates. Complaints are heard under all three heads, but most firms with experience in the ways of the market manage to do very well. As in so many other countries market promotion is a most important factor, and the most frequently neglected.

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American Droughts

By mid-summer this year, Britain's water engineers were becoming alarmed at the potential water situation if the year-old drought had continued. Fortunately for water engineers, but unfortunately for holidaymakers, August more than made good the rainfall deficiencies, and the drought of 1955–56 sank into the oblivion of droughts which " have been " and " might have been."

This pattern has followed the more severe droughts experienced in 1952–1955 in the State of Illinois, U.S.A. (reported in state bulletin No. 43). American water shortages were more severe than those experienced in Britain, principally because the drought was of greater intensity and longer duration, having a severity that would occur about once in 83 years. It is the standard story—rises in population, increases in domestic and industrial water requirements, reservoir siltation, and declines in well capacity, all coinciding with a peak drought.

American drought conditions appear to be much more severe than those experienced in Britain. For instance, once in a 100 years the annual stream yield of a catchment is expected to be less than 1 per cent. of the annual average, which indicates how relatively equable is the British climate. Hitherto the basic British standard of impounding reservoir design has been " the three dry years," despite the fact that Britain has never experienced three dry years. In Illinois during 1952–1955, this really occurred. The statistical approach parallels that by Mr. R. W. Thompson and Mr. Frank Law in recent *Journals* of the Institution of Water Engineers, and indicates the rapidly changing approach to water problems. The expected drought intensity can be estimated with some degree of accuracy, once in 30, 50 and 100 years. This solution to a difficult problem inevitably postulates a further problem, namely: should a community invest capital which, intended for use once in a century, is not fully operative 99 years in a 100? Fortunately, with the growing and continuous demands for water the second problem hardly ever arises, for what is a once-in-a-hundred chance to-day becomes a once-in-ten chance to-morrow through the growth in water demand, which transforms the effects of a minor drought into the effects of a major drought.

There is one danger in the statistical method in so far as the layman will assume that a frequency of once in 35 years means that when the peak drought is over, another one is not to be expected for another 35 years. Unfortunately nature is so capricious that it seems to have a way of not merely frightening people with drought or flood but also of giving them a sharp reminder soon after. Thus, one extreme followed by a similar climatic extreme was experienced in the Winnipeg floods both this century and the last. As yet the statistician cannot tell us when the next drought or flood will occur, yet that is what we really want to know.

* * *

British-American Television Co-operation

It has often been pointed out that while British scientists and research workers are pre-eminent in discovery it is left to those of other nations to bring about development of their results on a commercial basis. This point was reiterated by Mr. Dan Mitchell, chairman and president of Sylvania Electric Products Inc. of New York, at the official opening of the colour television research laboratories which his company and Thorn Electrical Industries, Limited, have established at Enfield. He emphasised his opinion in true transatlantic idiom and added that the two companies hoped to take mutual advantage of British research and American production techniques. Their primary object in building these laboratories, he went on, was to design a colour television receiver, which would be comparable in cost to existing black-and-white sets and equally simple to operate and maintain. To do this it might be necessary to invent a completely new type of colour tube. Research on similar co-operative lines would also be undertaken into solid-state devices, such as the transistor. On the occasion of the official opening, demonstrations were given on a closed circuit of coloured television films of both British and American origin which showed that great advances have taken place in this form of entertainment, although it is admitted that improvements are necessary and these will no doubt be made.

It was announced almost simultaneously that the British Broadcasting Corporation and the Independent Television Authority are to begin experiments on the transmission of colour television later in the present year. These experiments are to be carried out under the auspices of the Television Advisory Committee and will consist of a series of test signals on Bands I and III, the British 405-line system being used, the Crystal Palace transmitter of the Corporation and the Croydon transmitter of the Independent Television Authority being employed. Later colour signals will be transmitted on Band IV on the 625-line system. The outcome of all this work will be awaited with interest, but that it is being undertaken is an effective reply to the accusation that the possibilities of this form of entertainment are being neglected in this country.

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Telecommunications

It is customary for presidents of engineering and scientific institutions to devote their inaugural addresses to a survey of that branch of human activities with which they have been most intimately concerned. In the address, which he delivered to the Institution of Electrical Engineers last week, Sir Gordon Radley did not altogether depart from that precedent, although in dealing with telecommunications he devoted most of his attention to the future rather than the past or present. What he had to say did not lose interest on that account.

As regards internal development Sir Gordon

pointed out that the Post Office had a two-stage plan. The first, with which considerable progress had been made, was to install enough plant to meet the demand for a satisfactory telephone service. The second comprised the progressive mechanisation of the system so that long-distance dialling by the subscriber could be introduced and electronic register translators used for the dual purpose of routing the call and timing its duration. Electronic techniques were, he added, likely to revolutionise telephone switching in the near future and these were beginning to fall into two main types. The first used gas diodes or some other device for interconnecting the speech circuits in a space multiflex, while the second employed time-division multiflex for the same purpose. The speed with which these ideas could be realised in the form of a cheap and compact exchange depended on the production of suitable apparatus.

Turning to a wider prospect Sir Gordon gave it as his opinion that the recent completion of the transatlantic telephone cable had opened a new era in world telecommunication. That this development had been possible was due entirely to the submerged repeater. This device was revolutionary in that a cable so equipped could replace all the existing telephone and telegraph facilities on its route. This point was of particular interest to British engineers since we had a unique tradition in the manufacture of submarine cable; our research on thermionic valves and circuiting was likely to exercise a major influence on submarine repeater practice during the next decade; and Cable and Wireless, Limited, owned more than half the world's mileage of submarine telegraph cable.

As regards future potentialities, Sir Gordon said that it was best to start from traffic requirements. In this connection the relative merits of double and single-cable systems had been much debated, but whichever was chosen it was possible to work out an optimum design, although both technical and financial factors were involved. For instance, the maximum voltage which could be applied to the system to energise the repeaters, the minimum spacing at which it was practicable to insert them in the cable and the maximum size of the coaxial cable it was practicable to lay were all points to be considered, as were a number of practical problems connected with the laying itself and with maintenance. In telecommunications therefore, as in other branches of engineering, there will be plenty of scope for enterprise and still more for those who will display the necessary enthusiasm to exercise it.

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The Progress of Rolls-Royce

The retirement of Lord Hives from the chairmanship and the board of Rolls-Royce Limited may well mark the end of an era. For over 20 years the company have supplied the most advanced armament needs of the country. During that time the number employed has increased from 7,800 in 1935 (just before the start of the shadow factory expansion phase) to 37,000 to-day. Until fairly recently Rolls-Royce remained primarily what the City calls "an armament share." The problem now is to replace an immense turnover in military-aircraft and vehicle engines by products for civilian transport and peace-time industry. There is little doubt now that the demand for armaments will fall gradually and that in addition there is a tendency away from military aircraft to guided missiles and other types of weapons.

Lord Hives gave his working life to the company. His successor is taken from the world of banking and commerce. Lord Kindersley is chairman of Lazard Brothers, governor of the Royal Exchange Assurance, a member of the Court of the Bank of England and of several other banks and organisations. He was appointed to the board of Rolls-Royce in 1951 and may be said to have all the qualifications to give the company sound commercial leadership. He is not, however, chief executive officer, as Lord Hives was. This post is filled by Mr. J. D. Pearson, who will be a deputy chairman but will continue as managing director of the aero engine division. Mr. Whitney Straight will be the other deputy chairman. Mr. F. Llewellyn Smith continues as managing director of the motor car division and Mr. W. A. Robotham is appointed managing director of the Oil Engine Division. Of these four men three are engineers.

The oil engine division is a post-war development which has already been crowned with considerable success. The "C" series, as the range is known, is designed to power road and rail transport, for stationary and marine use and for mobile industrial plant. The motor-car division make, as well as cars, the "B" series petrol engine, originally developed for military road transport (over 20,000 have been made) and is now being installed in civilian transport vehicles, including airfield tractors, snowploughs, fire engines, coaches, ambulances, etc.; and a range of automatic gearboxes and transmission equipment. The excellent progress of the company's aero engine sales for civilian aircraft, in particular the Dart, has been reviewed in these columns on many occasions, but however widely these sales may spread, and however successful the Tyne (successor to the Dart), the Avon and the Conway may become, they are unlikely to fill the gap created by the reduction in armament orders.

Not surprisingly, perhaps, Rolls-Royce are at the forefront of development of new products, and not averse to taking up licences to quicken progress. One was taken out recently with North American Aviation Incorporated for full technical interchange of information on rocket motors. The acquisition of Sentinel (Shrewsbury) Limited gave the company a stake in automatic machine tools and in railway rolling stock (Weekly Survey: A Stake in Automation, September 14). Meanwhile development work goes on in all divisions, on the application of atomic energy to aircraft propulsion and related fields, on high altitude engine testing, etc. Much remains to be done to effect smoothly the changeover to "peace-time" demand.

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International Standards and Co-operation

The Export Panel of the British Standards Institution have recommended that the B.S.I. should co-operate to the full in the development of internationally agreed standards. The chairman of the panel is Mr. J. L. S. Steel, export director of I.C.I.; among the industrial members are Mr. Leslie Gamage, vice-chairman and joint managing director of the General Electric Company; Sir Ernest Goodale, chairman and managing director of Warner and Sons Limited; and Mr. Hector McNeil, deputy managing director of Babcock and Wilcox. This high-powered panel, appointed in 1954, have produced a crisply-worded short statement which may lead to a great deal of work on a great many drawing boards in British industry.

"The Export Panel believe that this country, with its dependence on exports to a wide variety of markets, will gain much more than it will lose by a policy aimed at securing the international acceptance of common standards for basic features. This is particularly important for those goods—and they form a vital section of British exports—where specification plays an important part in ordering." In their view, B.S.I. must "participate actively and with the best possible representation" on the committee of the International Organisation for Standardisation (I.S.O.) and of the Electrotechnical Commission (I.E.C.). Unless this is done, British exporters cannot expect their recommendations to be seriously considered by these two bodies. The panel point out that we cannot expect British Standards to be accepted abroad merely for traditional reasons but say also that wherever a well-conceived and widely accepted British Standard has existed its influence on the international recommendation has been considerable. They recommend that British Standards should therefore be developed in any field likely to be the subject of international consideration. The panel consider that British industry will greatly improve its competitive position overseas "for price, quality and service" if we are prepared to bring our standards "substantially into line with internationally agreed specifications, or with practices widely accepted overseas."

Another development last week which has a bearing on the subject, even if indirect, was Sir William Rootes' appeal to the British motor industry to co-operate among its individual units. Sir William is as export-conscious as any leading industrialist. He is chairman of the Dollar Exports Council and more clearly aware than most of the difficulties that arise when goods do not conform to international standards or even—as in the case of the British motor industry—to very many national ones. Sir William may not have wished to have been interpreted thus—he spoke of agreed minimum profits—but first British Standards, then international standards, would appear to offer most hope for steady progress of the industry in export markets.

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The James Watt Dinner

The James Watt Dinner of the Institution of Engineers and Shipbuilders in Scotland has become established as one of the major events in the engineering and shipbuilding fields, but the dinner which was held in Glasgow on October 4 had also a special significance, as it inaugurated the Institution's centenary year. The official celebrations of the centenary will be held in June next, but Sir Harold Yarrow, C.B.E., has already been installed as the Centenary President and it was under his chairmanship that the dinner was held. The toast of "James Watt" having been honoured—in silence, as the custom is—Sir Victor Shepheard, K.C.B., Director of Naval Construction, Admiralty, proposed that of "Engineering and Shipbuilding" in a speech which, while spiced with an agreeable humour, carried also a serious message for the industries whose representatives he was addressing.

Essentially, he said, shipbuilding and engineering were one profession, and one of its main problems was how to attract and to retain in it more of the best brains of the country, for undoubtedly Britain was falling behind other countries in that respect. The future of the twin industries must depend on the graduates from the universities, but the demand for engineering graduates was still much greater than the supply. In Russia, the United States, Germany and Japan that problem was being attacked on a scale that threatened increasingly severe competition and, though the British Government had decided to spend £100 million on providing additional facilities for technological education, that in itself was not enough; it was necessary to ensure also that the subsequent careers offered to those graduates were at least as attractive as those in other walks of life, and if possible more so. It was a problem that must be tackled on a national basis, and he suggested that the various engineering institutions and industries should set up a national committee to investigate it and to recommend means to make such careers more attractive. Having done this, they should organise propaganda throughout the public schools and grammar schools of the country to make known how the necessary qualifications could be obtained.

Professor A. M. Robb, who acknowledged the toast, emphasised the close ties of the Institution with the University of Glasgow, pointing out that it owed its inception to one of Glasgow's most famous professors, A. J. Macquorn Rankine. The year 1957, he added, also marked an important bicentenary in engineering development, for it was in 1757 that Glasgow University provided James Watt with facilities to establish himself there and so afforded him the opportunity to develop his genius.

Manchester Association of Engineers

The Manchester Association of Engineers have also been celebrating their centenary. The programme has included a service at the Cathedral, a civic reception, a banquet and visits to works. On October 1, the President, Mr. G. R. Adamson, M.I.Mech.E., gave his inaugural address, entitled " On Boiling Water," a subject which strikes at the heart of engineering.

In 1856, engineering was definitely coming to the fore in Manchester. Whitworth was demonstrating his new rifle barrelling, Beyer and Peacock had just built their first locomotive, and Sir William Fairbairn had published the first volume of his " Useful Information for Engineers." The time was therefore ripe for an organisation where engineering ideas, plans and developments could be discussed. The first title was somewhat grandiose—" The Association of Employers, Foremen and Draughtsmen of the Mechanical Trades of Great Britain "—but was retained until 1885, when the present one was assumed.

The increase of membership remained remarkably constant over the years—in 1858 it was 45, by 1863, 67—then a steady rise to a peak of 844 in 1922. Numbers fell off till 1941 and then began to rise again reaching a total of 644 during 1955. Throughout its existence, specialisation has been avoided, membership has been open to those concerned in all branches of engineering. Consequently there has always been opportunity to learn something of the other man's job—of his difficulties, his successes and, more important still in a closely linked economy, how developments in one field can help difficulties in another. Specialist societies are certainly needed where those with a common problem can meet to talk it out, but unless a generalised group (or journal) exists there can be no cross fertilisation between groups and a discovery that might change the face of industry could lie hidden away—dormant and sterile.

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Incentives for French Miners

Ever since it was created, when the industry was nationalised in 1947, the Charbonnages de France has been struggling to increase production. The chosen instrument has been the collective production bonus. Several types have been tried out, and the present system dates from July, 1950. Every year the management of the Charbonnages de France in conjunction with the Minister fixes targets for each coalfield; the coalfield management then fixes targets for each of its pits; and each coalfield reaching its target receives the bonus at the national level. A small addition or deduction is made to even out differences in conditions between different coalfields and pits.

Under the bonus system the worker is affected by the results achieved in his own colliery, in his own coalfield and in the nation as a whole. Production in short is a collective responsibility. The payment of bonuses depends on various factors. One is that strikes must not exceed eight days during the quarter. Another, to counter absenteeism, is that only periods of 14 days without absence count for bonus purposes. Exceptions are made for, among other things, accidents, compulsory military service and paid holidays.

The main bonus is paid out half-yearly at Christmas and the annual paid holiday. The system has met with a fair degree of success. Output per man-shift has risen from a national average of 748 kg. in 1950 to 1,045 kg. in 1955. The trade unions are not wholeheartedly in favour of the system. The anti-strike clause is strongly opposed and the bonus rates are disputed. Output is said to have risen more than wages. The biggest complaint is that miners and their union leaders are not given a big enough share in planning production targets. This complaint is heard at colliery group and coalfield level. All things considered, the Charbonnages de France and the National Coal Board appear to have a lot in common.

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Successor to the Diesel ?

The Pescara free-piston gasifier having Diesel pistons which are of less than 6 in. diameter may one day emerge as a serious competitor to the orthodox oil engine on road vehicles, railcars, launches, earth moving equipment, and other applications where light weight is important. At a Press conference held by the Free Piston Engine Company Limited (a member of the Associated British Engineering group), Mr. A. D. Mackay, the deputy-chairman, explained that the company hold an exclusive licence to make and sell this small gasifier in the U.K. and the British Commonwealth. Two other licensees, Renault in France and the General Motors Corporation in the United States, had developed " under-six-inch " gasifiers to the prototype stage. A small team of highly qualified engineers with experience of gas dynamics, gas-turbine and high-speed reciprocating engine design, as well as automotive engine applications, has been formed to undertake the development of a British prototype, under the direction of Mr. Stuart Mitchell, chief engineer of the A.B.E. group. Two machines, of 250 and 125 gas horse-power respectively, are being investigated. The prototype is expected to be ready towards the end of next year.

The attractions of such a power unit for automotive applications—which appear to be the main goal of all three licensees—are threefold. First, and probably foremost, is the possibility of achieving a multi-fuel engine able to run on residual fuels or 100-octane petrol. The second is the more favourable torque characteristic compared to a reciprocating engine, due to the shaft power being delivered by the turbine, and the third, which may greatly affect the cost of the unit, is that the high starting torque will enable the transmission to be simplified, probably down to a two-speed box for the average truck application.

Mr. Stuart Mitchell discussed some prototype test figures of fuel consumption of the G. M. gasifier, compared with petrol and Diesel engines and a gas turbine. These show a consumption of 0·48 lb. per b.h.p. per hour (at the turbine shaft) compared with 0·38 for the 4-stroke Diesel, 0·41 for the petrol engine and 0·75 for the gas turbine (0·60 projected). It might be added that on 2,000 h.p. sets, fuel consumptions of 0·38 lb. per b.h.p. per hr. have been achieved. The weight per b.h.p. on the other hand is only 3·6 lb. compared to 12·7 lb. for the 4-stroke Diesel. The thermal efficiency of the gasifier at full load based on gas horse-power is about 42 per cent.; taking a turbine efficiency of 80 per cent. the overall engine efficiency is 33·6 per cent.

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Points from the Chair

The season of company annual general meetings which begins in September is now in full swing. Each week as we go to press a dozen or more statements by chairmen of companies in the engineering, metal and allied industries are available for comment. The material is full of interest, and always enlightening. It is an old saying in the City that " the chairman knows best " and, true enough, what chairmen say of their companies' prospects is only rarely belied by events. The performance, plans, problems and hopes of others are always an intimate concern of competitors, suppliers or customers.

We will provide a regular review of all company reports available, picking out salient points, comparing and contrasting, bearing in mind throughout that it is industry's view of the future which is of greatest interest and value to industry. Remarks on falling profit margins, the need for increased capital to finance stocks and work in progress, the direction of technical change, research, diversification, export performance, are all topical and can be stimulating as well as informative. The practice of most chairmen to include in their reviews news of the latest developments that have taken place since the end of their companies' financial years—on supplies of materials and labour, flow of orders, impact of Government policy, and other important items—transforms their reports on a trading year that may have ended six months before into up-to-date informed comment and guidance on the prospects of the industries concerned. This week we have considered the reports of 16 companies.

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Expectations—Good and Bad

The keynote of the chairman's speeches reviewed this week is one of confidence in the future. True, all but three of the 16 companies reported higher trading profits, and to some extent therefore the reports were success stories. But the significant facts in the stories were—almost invariably—that fixed assets had increased in value, and that the inflow of work had exceeded deliveries. Most of the companies concerned were heavy or medium engineering units and there is so far little sign of any slackening in the rate of orders for the type of goods they make. Having to reduce prices to get orders—and particularly export orders—appears to be the main preoccupation of most companies, not a shortage of work.

Complaints about shortages takes less space than last year, but shortages remain and are serious threats to the competitive ability of several companies. The railway rolling stock builders—Gloucester Wagon, Hurst Nelson, and Cravens (John Brown and Company)—all complain of their inability to get adequate supplies of steel from British mills. Shortages of labour are also mentioned, but one company, Needman, Hender and Company—who make valves and a wide range of pipe fittings—overcame theirs by engaging Italian workers " in agreement with our employees." Their chairman, Mr. N. P. Newman, will doubtless be asked by other needy companies how this was done.

Of the many obstacles companies have to overcome the most obdurate and by far the most dangerous is the shortage of cash. The credit restrictions, heavy taxation of retained profits, and the controls exercised by the Capital Issues Committee, tend to hit hardest the medium to small companies who find it difficult to finance rising stocks and works in progress. But even the largest are affected: Lord Aberconway, chairman of John Brown, commented as follows on what is likely to become the basic problem of British engineering during the coming year: " The effect of inflation has been and still is to require even greater capital to finance a given volume of business, while the renewal of fixed assets, at greatly enhanced prices as compared with original cost, has absorbed, and continues to absorb, still further finance. . . . All the fields of activity in which the company is concerned required that the available manufacturing equipment should be of the latest design and of the highest practicable accuracy and economy. Only in this way can those businesses remain competitive."

Perhaps the most cheerful statement on the future comes from Mr. J. E. V. Jobson, chairman of Qualcast. This company have suffered a set-back during the past nine months owing to strikes and falling demand for the components they supply to the motor vehicle and electrical household appliances industries. These victims of the Government's squeeze on consumer spending have in the past 10 years multiplied output six times, including an increase of 9·7 per cent. last year. Now their customers are regaining confidence and Mr. Jobson anticipates that " the end of December should see us working at capacity again." Could it be that the great British public is becoming immune to Mr. Macmillan's medicine ?

ENGINEERING CONTRACTS

6—SOLVING LABOUR PROBLEMS

By F. H. B. Layfield

This is the sixth article of the series being contributed by Mr. Layfield for the guidance of engineers and others engaged on the preparation of engineering contracts. The fifth article appeared in ENGINEERING. *September* 28, 1956, *page* 393.

When an engineering contract is to be carried out, one of the largest problems to be tackled is that of labour. The difficulties involved affect the execution of work both at home and abroad and, though labour questions are to a marked degree ones which must be solved by good management, thought may usefully be given to them when preparing the contract. Some later troubles may be avoided if the more important aspects of labour supply and management are reviewed before the contract is concluded and steps taken to see that the contract sets out the main results of these deliberations.

The first decision to be made on labour is, naturally, who is to provide and pay for it. In regard to home contracts, the documents concerned, by defining the work to be done by the contractor, will often make clear by implication the fact that the contractor himself is to provide the necessary man power. When the work to be carried out is of a fairly simple kind this arrangement may be satisfactory, but, whenever complex works are to be erected, some express statement in the contract about the supply of labour is desirable. Very often, this will take a form similar to that set out in the Institution of Civil Engineers' General Conditions, which provide that: "Except where otherwise specified the contractor shall at his own expense supply and provide all . . . labour (including the supervision thereof) . . . required for the construction, completion, and maintenance of the works."

There are occasions, however, when phrases such as "except where otherwise specified" can lead to difficulties, since it is not, by any means, always clear when matters are "otherwise specified." If there are to be exceptions to a general provision that the contractor is to provide and pay for all labour, there is much to be said for stating those exceptions in clear terms, and for doing so in the clause which deals with the provision of labour. It will usually be the draftsman's job to set out the agreed labour arrangements clearly, but only the engineer can say effectively what these arrangements should be.

SKILLED AND UNSKILLED MEN

Contracts to be performed at home frequently have only a simple clause dealing with labour, and this leaves the whole matter to the contractor. With contracts to be carried out abroad the position is often more complex. Perhaps the most usual arrangement met with is that in which the contractor undertakes to provide all the skilled labour and the employer agrees to ensure a supply of local unskilled labour. It often happens that the employer, or his engineer, enjoy close or privileged relations with the appropriate foreign authorities and this makes such an arrangement desirable and effective. The way in which this kind of arrangement is dealt with in a contract must depend on the details of each case. Three points, however, may always be watched with profit in this connection. First, it is important to distinguish clearly in the contract between the duty to ensure a supply of labour or to secure access to labour, or similar undertakings, and the liability to make any kind of payment for it. Secondly, it is desirable to indicate clearly who is to be regarded as the actual employer of labour, whenever that labour is to be found or introduced or provided by a person other than the person actually managing the work. Thirdly, if a distinction is to be drawn between the provision of one class of labour and another, such as skilled and unskilled, care should be taken to establish clear meanings for the terms employed. The less use that is made of general phrases, and the more explicit the contract can be made, the less the likelihood of misunderstandings, both *bona fide* or otherwise. Therefore, if the engineer can state precisely what classes of workmen are to be provided, and by whom, the more satisfactory will be the result, wherever there is to be a division of responsibilities.

One of the main problems associated with labour nowadays is the occurrence of strikes. The avoidance of stoppages is, supremely, a manner for management and, accordingly it may be thought to have little connection with the drafting of contracts. In fact, there are a number of precautionary provisions which it may be thought wise to include in a contract, in appropriate circumstances. At the outset it should be said that, in the absence of express contractural arrangements, the law relating to the effect of strikes on contract work is somewhat uncertain. On this point, some shipping cases afford guidance by analogy, and, from these, it seems unlikely that a strike of fairly limited duration gives no excuse for failure to perform the contract work. On the other hand, a strike may last so long, or be so complete in its effects, that it will frustrate the contract. Therefore, to avoid uncertainties, it is usual to make explicit provisions in the contract about the effect of strikes upon the contractural obligations.

WAGES AND CONDITIONS

In general, the engineer will be interested more in the prevention of strikes than in their results. The usual causes of strikes are discontent with rates of pay or conditions of work, and it follows that there will be occasions, especially those involving very large programmes of construction, when it will be helpful to agree with the contractor on how these affairs can best be ordered, and to embody the agreed terms in the contract. The difficulty in such instances, as so often happens in legal matters, is to settle upon an arrangement whose meaning and effect is clear and unambiguous. Not only should the arrangements made be free from ambiguity at the time when the contract is signed, but consideration should be given as to whether this position will still apply should any important change in conditions occur. The most favoured way of making provision for these matters is by requiring that pay and conditions of work shall not be less favourable than those for the time being prescribed by some general recognised body. In the case of civil engineering contracts, the Institution of Civil Engineers' General Conditions provide, among other things, that: "The wages hours and conditions of employment . . . shall be those prescribed for the time being by the Civil Engineering Construction Conciliation Board for Great Britain . . ."

Even in adopting such an arrangement as this, however, the problem of conditions of labour is not necessarily solved. When a provision of this nature is included in the contract, it has usually been placed there to avoid disputes and, accordingly, it is vital that it should cover all reasonable contingencies. The draftsman will not usually know whether the selected reference body has established terms of employment to cover all the tradesmen and others likely to be concerned on the work. It is, therefore, for the engineer to satisfy himself that all the workmen he can foresee being required are embraced by the chosen reference code and that this code provides for all reasonably likely circumstances. If there are gaps in these provisions, it is likely that disputes will arise which could have been avoided. In attempting to fill any gaps which there may be in a pay code, or similar reference code, some ascertainable standard should be set. It is not desirable to try to settle the issue of, say, the levels of wages to be paid by a reference to "those prevailing in the area in which the work is to be done" or to "the general level observed by other employers whose circumstances are similar," if such vague standards can possibly be avoided. Expressions of this kind are susceptible of so many interpretations that they almost invite disputes.

Union membership among workmen employed on the site is another difficult question. There are employers who prefer to avoid dealing with this issue altogether and leave the matter to the contractor. The Institution of Civil Engineers' General Conditions deal with the matter by stipulating that: "The contractor shall recognise the freedom of his workpeople to be members of trade unions." There have, indeed, been occasions upon which it has been found desirable to provide that all workmen employed shall be members of one or other of the recognised unions and there may, doubtless, be times when troubles can be avoided by such a clause. The draftsman can readily include what may be required and it will pay the engineer, whatever view he holds on the matter, to consider carefully what he wishes done in this connection.

WORKMEN TO BE COMPETENT

If the contractor employs on the site workmen who are not competent this may have adverse effects upon the work. It is true that the employer usually possesses adequate powers to deal with any such unfortunate results; bad work can be removed and damages can be claimed, if delays arise. The interest of the engineer, however, is, usually and quite properly, less in obtaining remedies than in obtaining the right result at the right time. As a result, he will be concerned to see that the contract enables him to prevent defects rather than to cure them. Consequently, there is some value in having inserted in the contract a clause which requires that the contractor shall employ on the work, or on the site, "only such persons as are careful, skilled and experienced in their several trades and callings." This will usually be followed by an explicit provision enabling the engineer to require the removal of any person from the site or from employment, on or about the work, who is either incompetent, or negligent, or who misconducts himself. Engineers will not be slow to appreciate that such a clause has very real advantages for all parties in a number of difficult situations, though not all the advantages are apparent at first sight. Engineers will be well advised not to rely for such powers upon their implied authority under the contract, but to have adequate express power given to them in the contract, whenever works of any magnitude are to be executed.

It should be noted in connection with the power to require the removal of persons from employment on or about the works that the authority must be carefully expressed. In the first place, the engineer should decide whether he wishes the power to extend to all employees of the contractor or only to some of them. Secondly, the draftsman must see that these requirements are expressed in clear terms. It is by no means certain that this is the position brought about by some of the standard forms of contract. Engineers using printed forms will find it worthwhile to check on the point whenever this particular matter is of any importance.

Finally, there is the need to provide for accidents to workmen. Mention has been made in an earlier article of the importance of full and adequate insurance precautions. Accidents to workmen engaged on or about the works are a continual danger and deserve both special mention and special care. In the first place, it is desirable that the insurance of workmen should, in all but the simplest contracts, be dealt with in the contract as a separate matter. Secondly, the employer's interest in insurance

against accidents is chiefly to protect himself against claims for which he might otherwise be liable. This is a matter largely for the draftsman but the engineer is the person to whom insurance policies and receipts should normally be produced, and it is he who should decide upon the time and place for their production. As has been stressed previously, definite arrangements for the production of these documents is preferable to vague arrangements that the engineer may inspect them when he so decides. Arrangements made in respect of the contractor should, of course, be designed to embrace the sub-contractors also.

SUMMARY

Nowadays, labour problems are of major importance. Many of these problems are either purely technical or are those of management. However, some of these difficulties can and should be anticipated when the contract is drafted. They are mostly matters upon which the engineer must make decisions. The provision and supply of an adequate labour force are normally straightforward, but if the matter is not to be entirely the responsibility of the contractor, clear arrangements should be described in the contract. Labour questions are particularly important if the contract is to be carried out abroad. In order to reduce the likelihood of strikes, it may be useful to prescribe the rates of pay and conditions of work that shall prevail and, where this is done, it should be by means of reference to clear and recognised standards. These standards or codes should not only be clear and unambiguous but should also cover all the trades and categories of workmen likely to be employed, and all the circumstances likely to be met with, in the work. Uncertain arrangements should be avoided, as being likely to cause more arguments than they will avoid. For many reasons, the engineer may wish to require, from time to time, the removal of persons from the work or the site. If he wishes to obtain this authority, he should satisfy himself as to who the power will affect and, if he does not desire it to include everyone, that at least it does include the classes of people he has specified.

Insurance is never more important that in the case of accidents to workmen employed on or about the work, either by the contractor or the sub-contractors. Like insurance of other risks, the only way to make certain that the contractor has really effected the necessary insurance against such accidents is to require the production of the relevant policies and receipts. This production should take place at a stated time and place and not merely be left to someone's discretion.

HIGH-SPEED AIRCRAFT STRUCTURES

KINETIC HEATING AND THIN WINGS

" Structural Problems of High Speed Flight " was the theme of a three-day symposium held at the College of Aeronautics, Cranfield, organised by Professor W. S. Hemp, Head of the Department of Aircraft Design, from August 20 to 23, and attended by representatives of the British aircraft industry and leaders of relevant current research in British and overseas universities and establishments.

In the first paper, " Practical Design Problems of Supersonic Aircraft," by Mr. W. G. Heath, A. V. Roe and Company Limited, and Mr. B. O. Heath, English Electric Company Limited, the authors took a synoptic view of the many problems introduced by supersonic conditions, with the main emphasis on problems introduced by kinetic heating. Mr. B. O. Heath declared his principal interests as being related to stress, strain, creep and flutter, and he referred to the mutual dependence of the various special problems which can be treated severally by research workers but not by designers. The effect of the time-dependent heating of the structure at supersonic speeds had added new dimensions to the flight envelope, and a major concern of designers was the determination of critical design cases, a point which the speaker expounded in detail with the help of models. He went on to refer to the administrative difficulties introduced by the increasing complexity of supersonic specifications, and stressed the need for more design data sheets and wider adoption of automatic computing facilities, so that semi-skilled technical personnel could relieve the burden at present being carried by highly qualified engineering and scientific staff.

Mr. W. G. Heath, whose sphere of interest could, he said best be described in the colloquial idiom of " making, breaking and shaking," was concerned with the selection of materials for use at elevated temperatures, and with the problem of structural testing under simulated kinetic heating. The problem of materials, to which many other speakers returned in discussing this and other papers, culminated in the question of availability, since " no material, however suitable, is of any use to the aircraft designer unless it is available from the manufacturer at the time when it is needed; samples of new materials often show great promise for future structures, but an aircraft cannot be built from test pieces." Unless materials were produced in sheets and extrusions of the required lengths, widths, and thicknesses, their mechanical properties could not be utilised. Going on to the problem of full-scale testing, Mr. Heath said that the need to heat the surface of a structure would seem to mean the abandonment of tension patches—a good method recently developed—and the introduction of many new devices; he forecast the need to adopt closed-loop television for direct observation of a test when high temperatures and heating intensities prevailed.

Following this first session in which the whole sphere of interest had been surveyed, some key problems were considered in detail. From Mr. H. L. Cox National Physical Laboratory, came a timely reminder that elevated temperature is not the only burden to be carried by the designer of a supersonic aircraft structure. The need to maintain a high lift-drag ratio meant the least practicable dimension for the thickness of a wing, coupled with the lowest possible weight. In his paper on " The Design of a Thin Wing," Mr. Cox developed the theory of minimum weight structures, from the basic theorems established by Clerk Maxwell and A. G. M. Michell over 50 years ago, to embrace the modern types of cellular thin wing. He showed that there is no great difficulty in designing a wing of minimum weight for a particular loading specification, but the theory so far developed did not satisfactorily cover the problem of alternative loadings. He was doubtful, however, of the value of a detailed academic approach to the problem of simultaneously meeting the requirements of strength, divergence, and flutter, since the designer would find full scope for his art in meeting the alternative loading requirements in the manner best suited to production.

The remaining papers were all directly concerned with kinetic heating, but before the effect of heating a structure can be considered it is necessary to determine the temperature distribution as a function of time. This was the theme of Dr. H. Schuh, S.A.A.B., Sweden, who started from the incontrovertible proposition that text-book solutions and formal analysis cannot be applied to complicated structures. Finite difference methods were essential, and numerical solutions could then only be obtained with reasonable economy if the lumping of elements was no finer than necessary to obtain answers of engineering accuracy. He went a long way towards establishing a standard procedure for this type of calculation, by working out a few standard cases with a range of degrees of fineness of the relaxation net, and comparing the results with the rigorous analytical solution. This paper, when available, will no doubt become a standard reference in aircraft design offices.

Three of the lecturers were directly concerned with the effect of temperature on structural deterioration. As a contributor to the discussion remarked, temperature and thermal stress are not modes of failure, but there are several ways in which the combination of temperature effects and mechanical loads can lead to failure. Dr. E. W. Parkes, Cambridge University, in a paper on " Incremental Collapse Due to Thermal Cycles," showed that, in a typical thin wing of an aircraft rapidly accelerated to high supersonic speed and later decelerated, the temperatures of the skins and webs were always out of phase, and that with the addition of a constant bending moment, the non-recoverable plastic deformation would lead to progressive increase of wing-tip deflection. In a particular example, in which the physical conditions were unusually severe and the analytical simplifications enhanced the adverse effects, he computed a tip deflection of 10 per cent. of the span of the steel wing of a fighter aircraft after 20 flights. Making due allowance for the touch of exaggeration, if not hyperbole, which is within the licence of a lecturer launching a new hypothesis, Dr. Parkes gave a valuable and timely warning of the unfortunate consequences which may ensue if the effects of transient stresses in supersonic aircraft are not accurately assessed.

Professor Hoff's Polytechnic Institute of Berlin characteristic contribution, which adds new results of permanent value to the theory of thermo-elasticity and plasticity, presented the solutions of two relevant problems—the buckling of a panel under variable edge load, and a method of prediction of the time taken for a column to buckle due to material creep. Creep buckling, he suggested, might have an immediate application in the design of missiles in which the time of flight is short enough for the alleviating effect to be significant. In a prepared contribution to the discussion, Professor van der Neut gave an alternative solution of the panel buckling problem.

The outstanding contribution certainly in academic virtuosity and possibly also in its basic theoretical value, was that of Professor Bisplinghoff, Massachusetts Institute of Technology, who presented, in collaboration with Mr. John Dugundji, a considered introduction to the new science of thermo-aeroelasticity, extending, as he said, to a rectangle " Collar's famous aeroelastic triangle." In an application of the theoretical results to a conventional design problem, Professor Bisplinghoff, comparing three possible materials, deduced that " the titanium suffers a lesser relative reduction in stiffness than the steel or aluminium wings "; turning to the aeroelastic problems of lifting-surface divergence and aileron effectiveness, he showed that the effect of loss of stiffness on these phenomena is considerable. A final conclusion was that the importance of aeroelasticity relative to other design considerations will not be appreciably different in future aircraft where aerodynamic heating is considerable.

At the final session, Mr. J. Taylor, Royal Aircraft Establishment, outlined proposals for full-scale testing. Some items of equipment already developed included an electronic temperature recorder designed to read thermocouples at a mean rate of two a second with the results recorded on punched cards and by teleprinter simultaneously. Turning to the problems of simulating kinetic heating by radiant heat, Mr. Taylor outlined alternative methods of controlling the heat input, using analogue or digital computers to provide continuous assessments of the heat flux required at a number of stations over the surface of the structure. The problem of design conditions for the combined kinetic heating and loading test of a complete aircraft structure had been studied, and tentative suggestions were put forward for a simplified procedure, assuming that the simultaneous application of the most severe thermal and mechanical effects was statistically improbable.

RATIONAL DESIGN OF STAYED TUBE-PLATES

By J. P. Duncan, M.E., A.M.I.MECH.E., A.M.I.E.(AUST.)*

The circular tube-plates of some heat-exchangers are stayed to an adjacent rigid header or cover. The stays are symmetrically disposed about the centre of the plate and arranged along concentric circles or a diameter. The pressure differential across the tube-plate assembly is partly supported by the bending resistance of the perforated plate and partly by the forces induced in the stays by plate-deflection. Calculation of the loads to be resisted by the stays often follows arbitrary rules. The method described here rests upon the theories of eccentrically loaded plates developed by Föppl, 1912,[2]† and Michell, 1901,[4] and with theories of tube-plate rigidity reviewed in a recent paper by the author. The procedure, which employs the concept of a "group influence coefficient," has been presented in simplified form for design purposes.

Figs. 1(*a*) and 1(*b*) show two typical stayed tube-plates taken from actual installations. Fig. 1(*a*) shows a high-pressure feed-heater tube-plate with stays arranged along the bridge dividing the inflow and outflow drilled areas. Fig. 1(*b*) represents a small two-pass tube-plate from the floating end of an evaporator-vent condenser. Here the stays are arranged along a concentric circle.

With unstayed header to tube-plate combinations which have flange arrangements similar to those shown in Fig. 1(*a*), it is a fact of experience which can be supported theoretically (see Wesstrom and Bergh, 1951[6]) that when the header is pressurised, the gasket compression is reduced to a very small percentage of its initial value. The bolts-loads, however, change very little. For purposes of illustration, let it be assumed that the gasket-compression is entirely relieved under hydrostatic load and that the joint is just about to leak. The edge-condition of the plate then approaches simple support along the pitch-circle-diameter. With flanges of the type shown in Fig. 1(*b*) an encastré edge-condition is intended but is never fully realised in practice: no jointing arrangement is perfectly rigid.

It is clear from these two examples that the edge-restraint for any practical tube-plate is indeterminate and intermediate between a simply supported and an encastré condition. This point is discussed later in greater detail. At this stage it seems clear that in any theoretical treatment of the problem it will be necessary to assume one or other of these two edge-conditions. The effect of a relaxation from the assumed condition can usually be estimated qualitatively. If sufficient data are available, a quantitative estimate by the method of Wesstrom and Bergh, 1951,[6] may be possible. In the following analysis the simply supported and encastré edge conditions will be considered separately as two extremes.

The deflected middle planes of the simply supported and encastré plates, when loaded and unstayed, may be represented by the full lines in Figs. 2(*a*) and 2(*b*) respectively. If the header is assumed to be infinitely rigid and the plate is stayed to this header, the plate will take up some equilibrium position as shown dotted. The total hydrostatic force imposed on the plate by the pressure differential will then be resisted partly by the flexure of the plate to the dotted position and partly by the direct forces induced in the stays by the plate-deflection.

This statically indeterminate problem can be solved if (*a*) the rigidity of the perforated tube-plate is known and (*b*) if the deflections of eccentrically loaded circular plates with simply supported or encastré edges can be calculated.

The author has discussed requirement (*a*) elsewhere[3] and has shown that various forms of drilled plate—plate drilled continuously or to a one-, two- or four-pass pattern—can be reduced to equivalent undrilled plates having the same rigidity as the drilled.

The present article deals mainly with the second requirement (*b*). The solutions of the eccentrically loaded plate, in the forms developed by Föppl, 1912,[2] and Michell, 1901,[4] are put into suitable form for design purposes. The resulting rational method of analysis makes possible specific and comparative valuations of alternative stay and tube-plate arrangements. The loads in the stays of Fig. 1(*b*) as calculated by the method proved to be in very good agreement with subsequent measurements made on the header-tube-plate assembly during its manufacture.

STAYED TUBE-PLATES AS LOADED STRUCTURES

To calculate the stay-loads of the assembly as shown in Fig. 1(*a*), some simplifying assumptions must be made. The rigidity of both header and tube-plate and that of the stay connections to both members must be known. The simplifying assumptions of an infinitely rigid header and header-to-stay connection eliminate two real effects which may be allowed for by subsequent corrections based on experiment. Several tests on high-pressure feed-water heaters have shown that their headers behave like shells with comparatively flexible flanges. Bending deflections in the shell itself appear to be of a much lower order than in the unstayed tube-plate, particularly if the header incorporates a transverse baffle. The flexure of the header-flange imparts a small constant displacement to the tube-plate with respect to the otherwise rigid header. Take-up and resilience in a stay-nut and the screwed ends of a stay, together with that of any gasket or jointing which may be fitted under the nut, can be allowed for in an estimation of the effective stiffness of a stay. Experiments on several model tube-plates of similar proportions and drilling pattern (Duncan, 1955)[2] showed that tube-plates may be characterised by a "deflection efficiency," ρ, of which some specific values were obtained. This means that their deflections as unstayed plates would be $\frac{1}{\rho}$ times those of an undrilled plate of the same thickness, h_1. For purposes of analysis in this article, the tube-plate will be replaced by an equivalent undrilled plate of thickness $h' = \sqrt[3]{\rho}\, h_1$. This assumption is the subject of later discussion and experimental check and of theoretical examination in Reference 7.

In a practical installation, the stays must carry an initial tension sufficient to maintain contact between the stay-bosses and the tube-plate. Likewise the header-to-plate bolts will carry initial loads to establish gasket compression. The tube-plate will therefore be subjected to an edge-moment. In the following treatment it will be assumed that separation of the stay-bosses and the tube-plate occurs under load and that the gasket is just about to leak. The residual edge-moment is thus small. The stay-loads calculated under these conditions will then equal the minimum initial tension required in the stays if metal-to-metal joints are employed. The com-

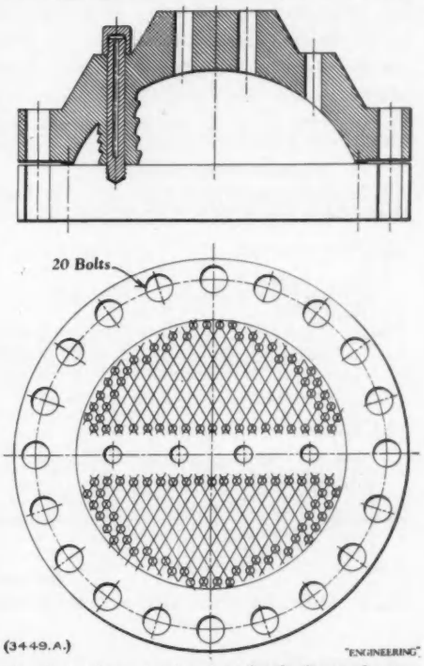

Fig. 1(a) Stayed tube-plate for feedwater heater.

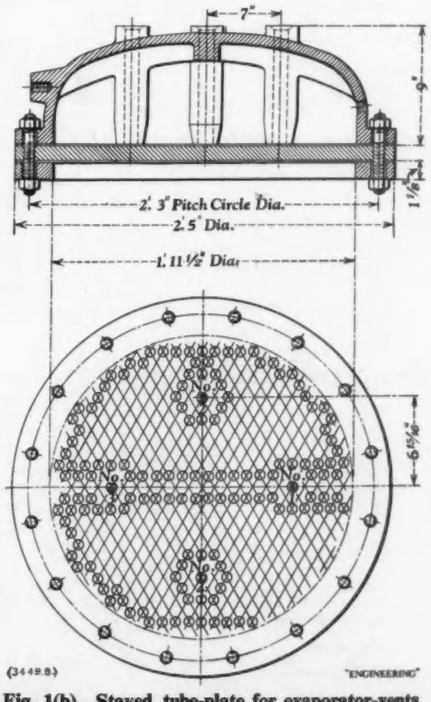

Fig. 1(b) Stayed tube-plate for evaporator-vents condenser.

NOMENCLATURE

a = Radius of support-circle at outer boundary of circular plate.
b = Radius of concentric loading circle.
c = Radius of inverse of point at radius p, $(c\,p = a^2)$
d = Diameter of stay.
g = a constant.
h = plate thickness; suffixes as defined.
i = denotes general suffix.
k = influence coefficient; suffixes as defined.
= length of stay under tension.
m = reciprocal of Poisson's ratio $= \frac{1}{\nu}$.
n = number of terms, number of stays.
p = distance of an eccentric load from plate-centre.
q = hydrostatic pressure.
r = general radius of points on a circular plate.
s, t = co-ordinates in Michell's inversion.
w = plate deflection; suffixes as defined.
x = ratio $\frac{p}{a}$ or ratio $\frac{b}{a}$, according to context.
y = influence ratio as defined.
A = stay area in tension; suffixes as defined.
B = a constant.
C = numerical coefficient with suffixes as defined.
D = plate rigidity; primes and suffixes as defined $D = \frac{E h^3}{12(1-\nu^2)}$.
E = Young's modulus of elasticity.
K = $\frac{1}{8\pi D}$.
L = a constant.
N = a constant.
P = uniformly distributed concentric load; suffixes as defined.
Q = a constant.
R = Fourier coefficients; primes and suffixes as defined.
S = $\frac{R}{K W a^2}$. Suffixes and primes as defined for corresponding values of R.
W = concentrated load at a point on a circular plate or total hydrostatic load; suffixes as defined.
ν = Poisson's ratio.
ρ = deflection efficiency. (See Reference 2).
θ = polar co-ordinate.
λ = correction factor as defined.
σ = tensile stress.

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† References will be given in the bibliography at the end of part 2 of this article, to be published later.

plication of an edge moment, which may be shown to be a function of the load (see Wesstrom and Bergh, 1951)[6] is also avoided in the analysis which follows. It could be reintroduced later as a load if sufficient is known about gasket resilience. Similarly, if the degree of prestressing and the stiffness of stay-bolts and associated gaskets are known, the change in the stay-load under pressure may be deduced by the standard method.

The plate is assumed to be loaded as shown in Fig. 3(*a*) (joint just leaking). The loading shown in Fig. 3(*b*) gives similar stress- and deflection-distributions to those resulting from Fig. 3(*a*) and calculations are thus simplified. This hydrostatic loading arrangement has been combined with the stay-loading in Fig. 2(*a*). The loading of the tube-plate, Fig. 1(*b*), is represented in Fig. 2(*b*). In this case the representation of hydrostatic loading is direct. The approximate theory of bending of thin plates has been employed throughout this article. The applicability of this theory to an undrilled circular plate is determined by the ratio $\frac{h^2}{a^2}$ and the accuracy of the results is always a matter of degree. Many tube-plates have a sufficiently low value of $\frac{h^2}{a^2}$ to warrant the use of the theory employed in conjunction with a deflection efficiency, ρ.

THEORETICAL ARGUMENT

Calculation of Load in a Single Stay.—Consider an equivalent circular plate of thickness h' tied to an infinitely rigid header by a single stay acting at a point A at radius p (Fig. 4(*d*)). Let the plate be either simply supported, as in Fig. 4(*d*), or encastré along the edge at radius a and let it be loaded with a uniform pressure q. The plate will deflect and the stay will extend until equilibrium is reached.

Let

$W_h = \pi a^2 q$ = total hydrostatic load,
W_s = Load induced in stay at equilibrium,
w_h = deflection at A produced by W_h when acting alone in the absence of W_s,
w_s = deflection at A produced by W_s when acting alone in the absence of W_h,
w_e = extension of the stay due to a force equal to W_s.

Then if $w_h = k_h W_h$, $w_s = k_s W_s$, $w_e = k_e W_s$, the factors k_h, k_s and k_e are "influence coefficients" for the loads W_h and W_s with respect to deflections of the plate at the stay location, and the extension of the stay itself. The factors k_i will be assumed onstant. They each represent a deflection per unit load.

At equilibrium

$$w_h = w_s + w_e$$
$$k_h W_h = (k_s + k_e) W_s$$
$$\therefore \quad W_s = W_h \left(\frac{k_h}{k_s + k_e}\right). \quad . \quad . \quad (1)$$

Equation (1) enables the stay-load, W_s, to be calculated provided the influence coefficients can be evaluated. Factor k_h can be found from the general expression for the deflection of a circular plate with uniformly distributed hydrostatic pressure q.

For a *simply supported edge*

$$w = \frac{q\,(a^2 - r^2)}{64\,D}\left(\frac{5+\nu}{1+\nu}a^2 - r^2\right)$$

(Timoshenko,[5] equation 67.)

$$\therefore \quad \frac{w_h}{\pi a^2 q} = k_h = \frac{a^2(1-x^2)}{64\pi D'}\left(\frac{5+\nu'}{1+\nu'} - x^2\right) \quad (2)$$

where $x = \frac{p}{a}$ and D′ and ν' are values of plate rigidity and Poisson's ratio respectively for the equivalent undrilled plate (see Duncan, 1955).[2]

For an *encastré edge*

$$w = \frac{q}{64\,D}(a^2 - r^2)^2 \quad \text{(Timoshenko,[5] equation 62).}$$

$$\therefore \quad \frac{w_h}{\pi a^2 q} = k_h = \frac{a^2}{64\pi D'}(1 - x^2)^2 . \quad (3)$$

where $x = \frac{p}{a}$ and D′ is the equivalent plate rigidity.

The factor k_e is easily evaluated as the ratio of the extension of the stay to the load required to produce it.

$$k_e = \frac{l}{E\,A} \quad . \quad . \quad (4)$$

where l = length of stay under tension,
A = cross-sectional area of stay,
E = Young's modulus of elasticity.

Finally, factor k_s can be found from the general expressions for deflections of eccentrically loaded plates with either simply supported or encastré edges. Though these expressions have been found they are complicated. The case with simply supported edges was solved by Föppl, 1912.[3] The encastré solution appears in Clebsch, 1862,[1] but its derivation by Michell, 1901,[4] is more convenient for present purposes. These solutions have been stated and discussed below, where they have also been reduced to suitable form for calculating k_s, appearing in equation (1). Since ρ, D′ and ν' can often be calculated theoretically or found experimentally (Duncan, 1955)[2] and since k_h, k_l and k_s can all be determined as described above, equation (1) represents a theoretical means of calculating the load in a single stay.

Plates with Several Stays.—Where more than one stay is employed, a set of simultaneous equations, equal in number to the number of stays, may be established along lines similar to those used above for a single stay. Since the number of stays usually employed is small and since the stays are usually arranged symmetrically about the centre of the tube-plate, it will be quite sufficient to consider first the general case of two asymmetrical stays. It will be shown later that several symmetrical stay arrangements of practical interest may be solved as special cases of this two-stay combination.

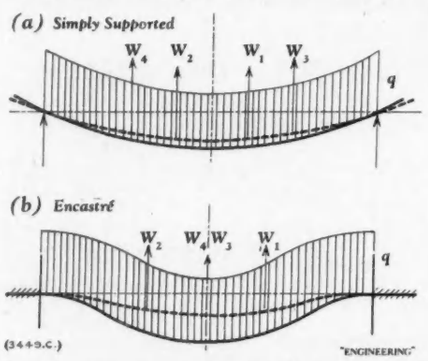


Fig. 2 Deflection of tube-plate with and without stays.

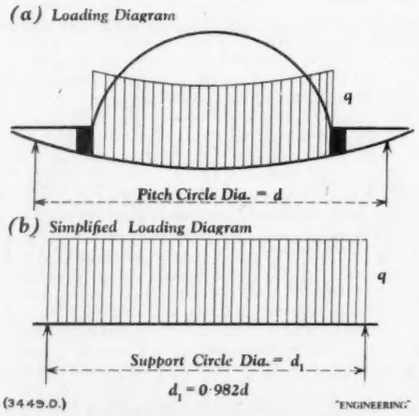


Fig. 3 Loading diagrams for plates in Fig. 1(a).

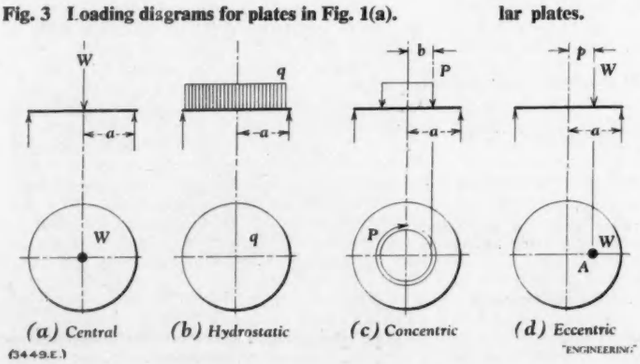


Fig. 4 (below) Graphical definition of loading arrangements on circular plates.

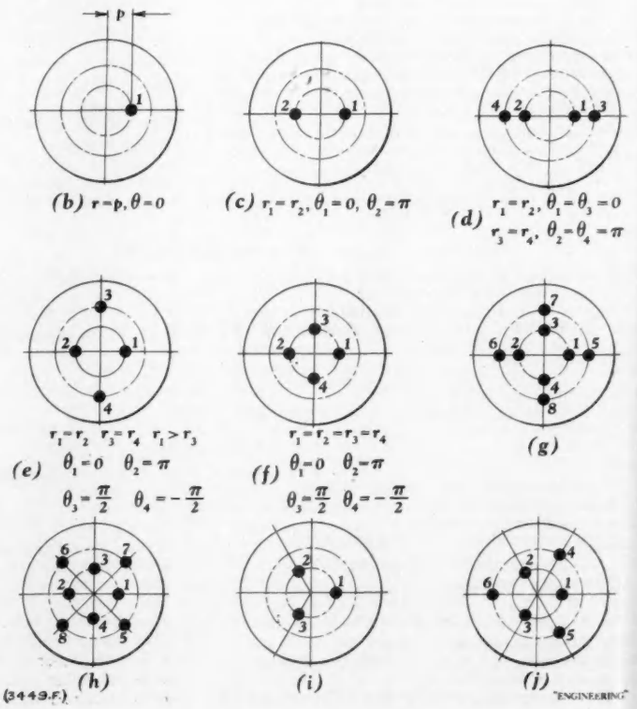
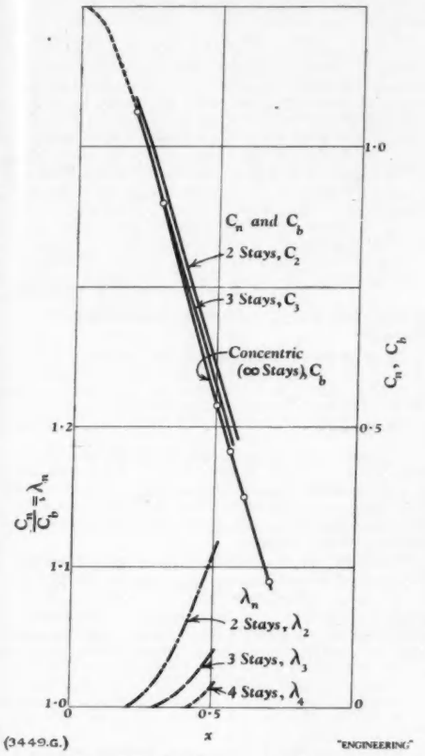


Fig. 5 (right) Stay arrangements for tube plates. Total deflection of the plate for multi-stayed arrangements is obtained by the principle of super-position.



See equations (22), (25) and (26)—curves require calculations of infinite series.

Fig. 6 Deflection ratios and coefficients for stay-load system and equal concentric loads.

The following applies for either a simply supported or an encastré edge. Let two stays connect the tube-plate to an infinitely rigid header or cover. Let the stays be located with respect to the centre of the plate and to a diameter by polar co-ordinates (r, θ) as shown in Fig. 5 (*a*).

Let

$k_{h1} W_h$ = deflection of unstayed plate at (r_1, θ_1) due to W_h.
k_{s11} = deflection of plate at (r_1, θ_1) due to unit load at (r_1, θ_1).
k_{s21} = deflection of plate at (r_1, θ_1) due to unit load at (r_2, θ_2).
k_{s12} = deflection of plate at (r_2, θ_2) due to unit load at (r_1, θ_1).
k_{s22} = deflection of plate at (r_2, θ_2) due to unit load at (r_2, θ_2).
k_{c1} = extension of stay at (r_1, θ_1) due to unit load.
k_{c2} = extension of stay at (r_2, θ_2) due to unit load.
W_{s1} = load in stay at (r_1, θ_1).
W_{s2} = load in stay at (r_2, θ_2).

Then, at equilibrium,

$$k_{h1} W_h = W_{s1} k_{s11} + W_{s1} k_{c1} + W_{s2} k_{s21} \quad . \quad (5)$$

$$k_{h2} W_h = W_{s2} k_{s22} + W_{s1} k_{c2} + W_{s2} k_{s12} \quad . \quad (6)$$

Again, the stay-loads W_{s1} and W_{s2} can be found from (5) and (6) providing the appropriate influence coefficients can be evaluated. This can be done by using equations (2) to (4) together with the general solutions for eccentrically loaded plates given below.

If the two stays are symmetrically disposed about the centre of the plate as in Fig. 5(*c*), where $r_1 = r_2$ and $\theta_2 = \theta_1 + \pi$, obviously $W_{s1} = W_{s2}$, $k_{s11} = k_{s22}$, $k_{s12} = k_{s21}$, $k_{h1} = k_{h2}$ and $k_{c1} = k_{c2}$. (The last equality is not essential but is usual.) Therefore both equations (5) and (6) reduce to identical form

$$k_{h1} W_h = W_{s1} k_{s11} + W_{s1} k_{c1} + W_{s1} k_{s12}$$

$$W_{s1} = W_{s2} = W_h \frac{k_{h1}}{(k_{s11} + k_{s21}) + k_{c1}} \quad (7)$$

Equation (7) is identical in form to equation (1) but k_s is now replaced by $(k_{s11} + k_{s21})$. Evaluation of this bracketed term is no more difficult, though more tedious, than finding k_s.

It is easy to see how this treatment could be extended to four stays symmetrically disposed about the centre. The two arrangements shown in Fig. 1(*a*) and 1(*b*) are usual. Using a system of notation similar to that adopted above, the equations for the arrangement shown in Fig. 5(*d*) are

$$k_{h1} W_h = W_{s1} (k_{s11} + k_{s21}) + W_{s2} (k_{s21} + k_{s41}) + W_{s1} k_{c1} . \quad (8)$$

$$k_{h2} W_h = W_{s2} (k_{s22} + k_{s42}) + W_{s1} (k_{s12} + k_{s32}) + W_{s2} k_{c2} . \quad (9)$$

$$W_{s1} = W_{s3} . \quad . \quad . \quad (10)$$

$$W_{s2} = W_{s4} . \quad . \quad . \quad (11)$$

The solution of equations (8) to (11) is little more difficult than that of equations (5) and (6).

For an arrangement as in Figs. 1(*b*) and 5(*f*), all four stay-loads must be equal and given by

$$W_{s1} = W_h \frac{k_{h1}}{(k_{s11} + k_{s21} + 2 k_{s21}) + k_{c1}} . \quad (12)$$

$$W_{s1} = W_{s2} = W_{s3} = W_{s4} . \quad . \quad . \quad (13)$$

Equation (12) again resembles equation (1). The term $(k_{s11} + k_{s21} + 2 k_{s21})$ has replaced k_s. This new term in brackets and others like it in equations (7), (8), (9) and (12) will be defined as group influence coefficients. The evaluation of these factors in general terms is the principal theme of the two following sections of this article.

In symmetrical arrangements of n identical stays at a common radius, p, the group influence coefficients for stay and for hydrostatic loading are both functions of p. The stay coefficient is also a function of n. The factor k_{h1} may therefore be written as k_h and the group influence coefficient for the stay system as k_{sn}. Since it is always necessary to calculate k_h from the comparatively simple formulae for hydrostatic loading (equations (2) or (3)), it is convenient to express k_{sn} as a multiple of k_h. This dimensionless ratio, $\frac{k_{sn}}{k_h}$, will be referred to as "influence ratio," a function of p denoted by y_{pn}. This ratio is independent of plate rigidity

$$y_{pn} = \frac{k_{sn}}{k_h} . \quad . \quad . \quad (14)$$

Using this notation, equations (7) and (12) may be written

$$W_{s1} = W_{s2} = W_h \left(\frac{k_h}{y_{p2} k_h + k_{c1}} \right) . \quad . \quad (7(a))$$

$$W_{s1} = W_{s2} = W_{s3} = W_{s4} = W_h \left(\frac{k_h}{y_{p4} k_h + k_{c1}} \right) . \quad . \quad . \quad . \quad (12(a))$$

In general, if W denotes the sum of n equal stay-loads in a symmetrical system of identical stays

$$W = n W_{s1} = n W_h \left(\frac{k_h}{y_{pn} k_h + k_{c1}} \right) . \quad (15)$$

or

$$W_h = W \left(\frac{y_{pn}}{n} + \frac{k_{c1}}{n k_h} \right) . \quad . \quad . \quad . \quad (16)$$

By comparing equation (15) with equation (1) it can be seen that for purposes of mathematical solution, a symmetrical system of identical stays can be treated as a single stay at radius p carrying a total load W. It is only necessary to use a group influence coefficient in lieu of an influence coefficient. Further development of these ideas shows that two series of symmetrically arranged stays as shown in Figs. 5(*g*), 5(*h*) and 5(*j*) can be solved by two equations similar to (5) and (6). To do this the appropriate influence coefficients expressed as influence ratios are required.

PLATES WITH SIMPLY SUPPORTED EDGES

Eccentric Loading of Circular Plate with Simply supported Edges.—The general expression for the deflections in an eccentrically loaded isotropic circular plate of rigidity D with a simply supported edge was found by Föppl, 1912.[3] His method of derivation resembles that which Clebsch, 1862,[1] applied to the eccentrically loaded plate with an encastré edge. Föppl's solution is

$$w = R_0 + R_1 \cos\theta + R_2 \cos 2\theta \ldots + R_n \cos n\theta \quad . \quad . \quad . \quad (17)$$

where θ is a polar co-ordinate of sense shown in Fig. 5 (*a*) and the load W is applied at $(r = p, \theta = 0)$ (Fig. 5 (*b*)). If the point at which deflection is required is at a radius greater than p, then

$$R_0 = \frac{W a^2}{8 \pi D} \left\{ \frac{3 m + 1 - (m-1) \frac{p^2}{a^2}}{2 (m+1)} \left(1 - \frac{r^2}{a^2}\right) - \frac{r^2 + p^2}{a^2} \log \frac{a}{r} \right\}$$

$$R_1 = \frac{W a^2}{8 \pi D} \left\{ \frac{m+1}{3m+1} \frac{rp}{a^2} \cdot \frac{r^2 + p^2 - a^2}{a^2} + \frac{m-1}{2(3m+1)} \frac{r^3 p^3}{a^6} - \frac{p^3}{2 a^2 r} + \frac{2 r p}{a^2} \log \frac{a}{r} \right\}$$

$$R_n = \frac{W a^2}{8 \pi D} \frac{1}{n(n-1)} \left\{ \left(\frac{p}{r}\right)^n \left(\frac{r^2}{a^2} - \frac{n-1}{n+1} \frac{p^2}{a^2} \right) + \left(\frac{r}{a} \frac{p}{a}\right)^n \frac{\left[(m+1)(n-1) \frac{p^2}{a^2} - (3m+1) n + (m+1)(n-1) \frac{r^2}{a^2} + (m-1) \frac{n(n-1)}{(n+1)} \frac{p^2 r^2}{a^4} \right]}{m(2n+1)+1} \right\} .$$

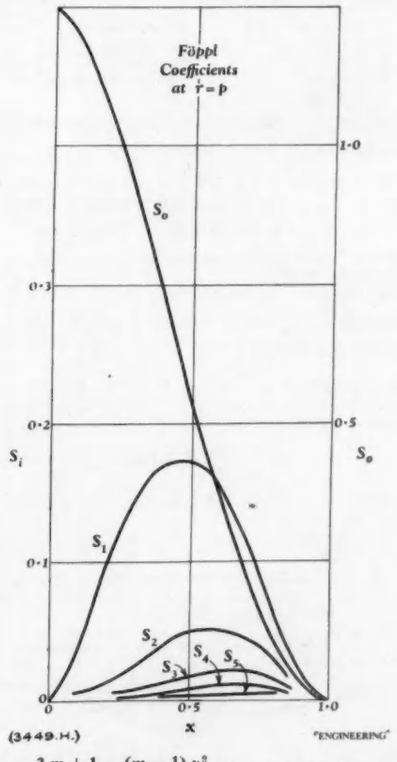
If the point at which deflection is required is at a radius less than p, then coefficients R are replaced by R′ where

$$R'_0 = \frac{W a^2}{8 \pi D} \left\{ \frac{3m+1-(m-1)\frac{r^2}{a^2}}{2(m+1)} \left(1 - \frac{p^2}{a^2}\right) - \frac{r^2 + p^2}{a^2} \log \frac{a}{p} \right\}$$

$$R'_1 = \frac{W a^2}{8 \pi D} \left\{ \frac{m+1}{3m+1} \frac{rp}{a^2} \cdot \frac{r^2 + p^2 - a^2}{a^2} + \frac{m-1}{2(3m+1)} \frac{r^3 p^3}{a^6} - \frac{r^3}{2 a^2 p} + \frac{2 r p}{a^2} \log \frac{a}{p} \right\}$$

$$R'_n = \frac{W a^2}{8 \pi D} \frac{1}{n(n-1)} \left\{ \left(\frac{r}{p}\right)^n \left(\frac{p^2}{a^2} - \frac{n-1}{n+1} \frac{r^2}{a^2} \right) + \left(\frac{r}{a} \frac{p}{a}\right)^n \frac{\left[(m+1)(n-1) \frac{p^2}{a^2} - (3m+1) n + (m+1)(n-1) \frac{r^2}{a^2} + (m-1) \frac{n(n-1)}{(n+1)} \frac{p^2 r^2}{a^4} \right]}{m(2n+1)+1} \right\} .$$

Equation (17) enables all the group influence coefficients discussed above to be evaluated for



$$S_0 = \frac{3m+1-(m-1)x^2}{2(m+1)} (1 - x^2) + 2 x^2 \log x .$$

$$S_1 = \frac{m+1}{3m+1} (2x^4 - x^2) + \frac{m-1}{2(3m+1)} x^6 - \frac{x^2}{2} - 2 x^2 \log x .$$

$$S_n = \frac{1}{n(n-1)} \left[\frac{2}{n+1} x^2 + x^{2n} \times \frac{8(n-1)x^2 - 10n + 2 \frac{n(n-1)}{n+1} x^4}{3(2n+1)+1} \right] .$$

Fig. 7 Föppl coefficients for r-p as functions of x.

simply supported edges but when coefficients, R_i, are substituted in full, it becomes a most unwieldy expression. Simplification is made difficult by the awkward boundary condition of zero bending moment with variable slope and by the appearance of $m = \frac{1}{\nu}$, the reciprocal of Poisson's ratio. The latter will, of course, vary with the material used and the drilling pattern. For these reasons, no attempt has been made here to present equation (17) in graphical form as a function of parameters p, r θ and m. Instead, by the consideration of the special case where $p = r = x\,a$ and $m = 3$, it will be shown that a series of stays arranged along a concentric circle can be treated within certain accuracy as a uniformly distributed concentric load. Group influence coefficients can then be calculated from the simple expressions for this latter form of loading.

Simply Supported Plate with Loads at Half Outer Radius.—In equation (17) let

$$R_{\text{suffix}} = K\,W\,a^2\,S_{\text{suffix}}.$$

In the following special case, let $\frac{r}{a} = \frac{p}{a} = x$.

Then

$$S'_0 = S_0 = \frac{3m+1-(m-1)x^2}{2(m+1)}(1-x^2) + 2x^2\log x$$

$$S'_1 = S_1 = \frac{m+1}{3m+1}(2x^4 - x^2) + \frac{m-1}{2(3m+1)}x^6 - \frac{x^2}{2} - 2x^2\log x$$

$$S'_n = S_n = \frac{1}{n(n-1)}\left\{\frac{2}{n+1}x^2 + x^{2n}\frac{8(n-1)x^2 - 10n + 2\frac{n(n-1)}{n+1}x^4}{3(2n+1)+1}\right\}.$$

Letting $x = \frac{1}{2}$ and $m = 3$

$S_0 = 0{\cdot}544$	$S_5 = 0{\cdot}004$
$S_1 = 0{\cdot}173$	$S_6 = 0{\cdot}002$
$S_2 = 0{\cdot}049$	$S_7 = 0{\cdot}001$
$S_3 = 0{\cdot}018$	terms decreasing
$S_4 = 0{\cdot}008$	

Consider the deflection under the single concentrated load in Fig. 5(*b*). Here $\theta = 0$, $r = \frac{a}{2}$.

$$\therefore\quad w_1 = K\,W\,a^2\,(0{\cdot}544 + 0{\cdot}173 + 0{\cdot}049 + 0{\cdot}018 + 0{\cdot}008 + 0{\cdot}004 + 0{\cdot}002 + 0{\cdot}001)$$

or $$w_{p1} = K\,W\,a^2\,0{\cdot}799 \quad . \quad . \quad . \quad (18)$$

where w_{p1} denotes deflection under a single load W at radius p.

The deflection under each of two concentrated loads each $\frac{W}{2}$ acting simultaneously at points 1 and 2 as in Fig. 5(*c*) will be

$$w_1 = w_2 = K\,W\,a^2\left(\frac{0{\cdot}799}{2} + \tfrac{1}{2}[0{\cdot}544 - 0{\cdot}173 + 0{\cdot}049 - 0{\cdot}018 + 0{\cdot}008 - 0{\cdot}004 + 0{\cdot}002 - 0{\cdot}001]\right)$$

or $$w_{p2} = K\,W\,a^2\,0{\cdot}604 \quad . \quad . \quad (19)$$

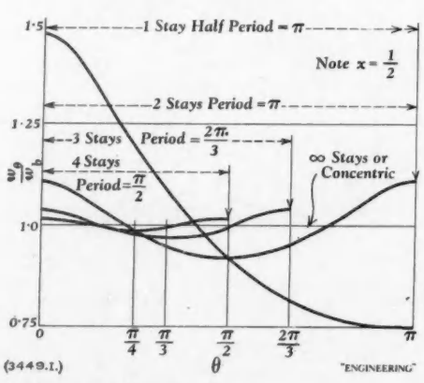


Fig. 8 Variation in deflection along loading circles of radius p.

$$\left(\frac{w_\theta}{w_b}\right)_{(n=1)} = \frac{1}{0{\cdot}544}(0{\cdot}544 + 0{\cdot}173\cos\theta + 0{\cdot}049\cos 2\theta + 0{\cdot}018\cos 3\theta + 0{\cdot}008\cos 4\theta + 0{\cdot}004\cos 5\theta + 0{\cdot}002\cos 6\theta + 0{\cdot}001\cos 7\theta + \ldots.)$$

where w_{p2} denotes deflection under each of loads $\frac{W}{2}$ at radius p. The term in square brackets is found by equating θ to π in equation (17). It represents the effect at point 1 of the load at point 2.

The deflection under each of three equal concentrated loads, $\frac{W}{3}$, acting simultaneously at points 1, 2 and 3 of Fig. 5(*i*) will be

$$w_1 = w_2 = w_3 = K\,W\,a^2\left(\frac{0{\cdot}799}{3} + \frac{2}{3}\left[0{\cdot}544 - \frac{0{\cdot}173}{2} - \frac{0{\cdot}049}{2} + 0{\cdot}018 - \frac{0{\cdot}008}{2} - \frac{0{\cdot}004}{2} + 0{\cdot}002\right]\right)$$

or $$w_{p3} = K\,W\,a^2\,0{\cdot}564 \quad . \quad . \quad (20)$$

The term in square brackets is found by equating θ to $\frac{2\pi}{3}$ in equation (17) and represents the effect at point 1 of a load, W, applied at either point 2 or point 3.

In a similar way, the deflections under each of four equal concentrated loads $\frac{W}{4}$ acting simultaneously at points 1, 2, 3 and 4 in Fig. 5 (*f*) will be

$$w_1 = w_2 = w_3 = w_4 = K\,W\,a^2\left(\frac{0{\cdot}799}{4} + \tfrac{1}{4}[0{\cdot}407] + \tfrac{1}{4}\{0{\cdot}544 - 0{\cdot}049 + 0{\cdot}008 - 0{\cdot}002\}\right)$$

or $$w_{p4} = K\,W\,a^2\,0{\cdot}553. \quad . \quad (21)$$

The term in parentheses is found by equating θ to $\frac{\pi}{2}$ in equation (17) and represents the effect at point 1 of a load W, applied at points 3 or 4.

If a uniformly distributed load, P, equal to the sum of the stay-loads, W, is distributed round the circle of radius $b = \frac{a}{2}$, the deflection at radius b can be calculated from the general expression for the deflection under the load in a concentrically loaded plate. Thus

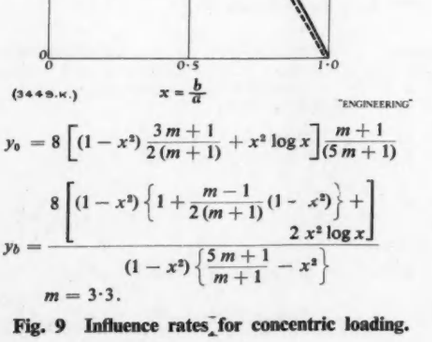
$$w_{(r=b)} = \frac{P}{8\pi D}\left[(a^2-b^2)\left(1+\tfrac{1}{2}\frac{1-\nu}{1+\nu}\frac{a^2-b^2}{a^2}\right) + 2b^2\log\frac{b}{a}\right].$$

(Timoshenko[5] equation (*e*), page 70.)

In the notation of this article

$$w_b = K\,P\,a^2\left[(1-x^2)\times\left(1+\tfrac{1}{2}\frac{m-1}{m+1}(1-x^2)\right) + 2x^2\log x\right]$$

$$w_b = K\,P\,a^2\,C_b. \quad . \quad . \quad . \quad . \quad . \quad (22)$$


Simple Edge Support
y_b = Ratio Hydrostatic to Concentric Load Producing Same Deflection Under the Concentric Load
y_o = Ratio Hydrostatic to Concentric Load Producing Same Central Deflection
a = Support Radius
b = Radius Concentric Load
y_b, y_o
x = b/a
(3449.K.)
"ENGINEERING"

$$y_o = 8\left[(1-x^2)\frac{3m+1}{2(m+1)} + x^2\log x\right]\frac{m+1}{(5m+1)}$$

$$y_b = \frac{8\left[(1-x^2)\left\{1+\frac{m-1}{2(m+1)}(1-x^2)\right\} + 2x^2\log x\right]}{(1-x^2)\left\{\frac{5m+1}{m+1} - x^2\right\}}$$

$m = 3{\cdot}3.$

Fig. 9 Influence rates for concentric loading.

For the special case considered above where $m = 3$ $x = \frac{1}{2}$

$$w_b = K\,P\,a^2\,0{\cdot}544. \quad . \quad . \quad (23)$$

In all the cases represented by equations (18) to (21) and equation (23), the deflection of the centre of the plate will be exactly the same providing P = W. This follows without further proof from the symmetry of the plate-boundary about the plate-centre. (See Timoshenko, page 73).[5] From the equation for the deflection within a concentric load at radius b

$$w = \frac{P}{8\pi D}\left[(a^2-b^2)\times\frac{(3+\nu)a^2 - (1-\nu)r^2}{2(1+\nu)a^2} + (b^2+r^2)\log\frac{b}{a}\right]$$

(Timoshenko,[5] equation 78)

the central deflection is given, in the notation of this article, by

$$w_0 = K\,P\,a^2\left[(1-x^2)\frac{3m+1}{2(m-1)} + x^2\log x\right].$$

For $m = 3$, $x = \frac{1}{2}$,

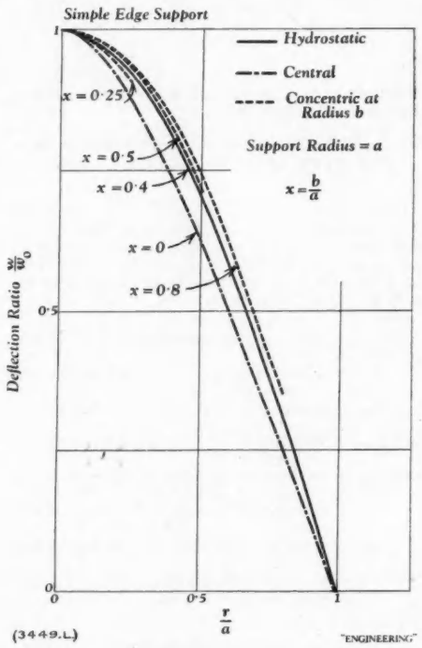
$$w_0 = K\,P\,a^2\,0{\cdot}764. \quad . \quad . \quad . \quad . \quad . \quad (24)$$

It is apparent from a comparison of equations (19), (20) and (21) with equation (23) and from the reasoning leading to equation (24) that a symmetrical stay arrangement becomes more nearly equivalent to concentric loading as the number of stays increases from $n = 2$ to $n = \infty$.

Equations (18) to (21) may be expressed in general form

$$w_{pn} = K\,W\,a^2\,C_n. \quad . \quad . \quad (25)$$

where $n = 1, 2, 3 \ldots . \infty$ and C_n is a numerical coefficient appropriate to the symmetrical arrangement of n stays. Equation (22) is of similar form to



For hydrostatic loading:

$$\frac{w}{w_0} = \left\{1-\left(\frac{r}{a}\right)^2\right\}\left\{\frac{5m+1}{m+1} - \left(\frac{r}{a}\right)^2\right\}\frac{m+1}{5m+1}$$

For concentric loading:

$$\frac{w}{w_0} = \frac{\left[\left[\left(x^2+\left(\frac{r}{a}\right)^2\right)\log x + (1-x^2)\frac{3m+1-(m-1)\left(\frac{r}{a}\right)^2}{2(m+1)}\right]\right]}{x^2\log x + (1-x^2)\frac{3m+1}{2(m+1)}}$$

For central loading:

$$\frac{w}{w_0} = \frac{\frac{3m+1}{m+1}\left\{1-\left(\frac{r}{a}\right)^2\right\} + 2\left(\frac{r}{a}\right)^2\log\frac{r}{a}}{\frac{3m+1}{m+1}}$$

Fig. 10 Deflection distribution for central, hydrostatic and concentric loading.

equation (25). The coefficients C_n and C_b appearing in these two equations have been plotted as functions of x in Fig. 6.

Values in Fig. 6 have been computed in a similar manner to that used above for $x = \frac{1}{4}$. These calculations are tedious, and beyond $x = \frac{1}{2}$ demand better than slide-rule accuracy. Coefficients S_i, where $i = 1, 2, 3 \ldots . \infty$, as plotted in Fig. 7, must first be obtained. From the values of S_i at each specific value of x the coefficients C_n are obtained for $n = 1, 2, 3 \ldots . \infty$.

For specified values of x in a practical design, especially where $x > \frac{1}{4}$, this procedure of calculation may be preferred to any alternative method. In many cases, however, it may be more convenient to calculate C_b for a concentric load $P = W$ and to apply a correction factor, λ, as given in Fig. 6 where

$$\lambda = \frac{C_n}{C_b}. \quad . \quad . \quad (26)$$

It will be seen that λ is so nearly equal to unity for three and four-stay arrangements, where $x < \frac{1}{2}$, that it might well be neglected. If exact group influence coefficients are required, these can be computed from

$$k_{sn} = \frac{w_{pn}}{W} = K a^2 C_n = K a^2 \lambda C_b. \quad (27)$$

For all symmetrical combinations of stays at one radius p, the deflection along the circle of radius p will vary with θ. The extent of this variation is shown in Fig. 8 for the special case of $x = \frac{1}{2}$. When the number of stays exceeds two, this variation is so slight that the loading combination can be regarded as concentric (no variation in deflection with θ). The formulae for this form of loading may then be used to calculate deflections caused by the combination at any point on the plate surface.

It has thus been shown that any combination of stays, all at radius r, can be reduced to an equivalent uniformly distributed concentric load at the same radius. If two series of stays act at radii r_1 and r_2 respectively, the equivalent concentric loads P_1 and P_2 can be substituted in equations (5) and (6) for W_{s1} and W_{s2}, respectively, and their influence coefficients for k_{s11}, k_{s12}, k_{s22} and k_{s21}. (See Timoshenko,[5] equations 77 and 78* for the calculation of k_{s12} and k_{s21}, respectively). In this way any combination of stays located at two radii r_1 and r_2, as in Fig. 5(*e*) to (*j*), can be solved theoretically by means of equations (5) and (6).

DESIGN DATA CHARTS

In Fig. 4 the various loading arrangements mentioned so far are shown in addition to central loading. It will be noticed from equations (1), (5), (6) and (7) that it is always necessary to calculate influence coefficients for hydrostatic loading from the simple relationships (2) or (3). When stays are located at one radius only, and provided tube-plates may be regarded as isotropic, it will therefore be convenient to express k_{sn} for the equivalent concentric load as a multiple of k_h in a manner previously described for concentrated load-combinations. This has been given as y_b in Fig. 9. The ratio y_a as given and defined in Fig. 9 may also be used in lieu of y_b although it is not theoretically correct to do so. This substitution is possible because $y_a \simeq y_b$ for all values of x. The reason for this is made clear from Fig. 10, which gives deflection-distribution curves for concentric and hydrostatic loading. These curves are nearly the same for a wide range of x. The use of y_a in lieu of y_b represents a final simplification of the theory presented. It is simpler to compare central deflections for any form of loading than off-centre deflections. An example of the use of charts of this nature is given later.

* For convenience, these equations will be given in Appendix I.

ECCENTRIC LOADING TEST

Experiments were conducted on the experimental tube-plate shown in Fig. 11 to test the validity of substituting an equivalent plate of thickness $h' = \sqrt[3]{\rho}\, h_1$ for the actual tube plate of thickness h_1 and to demonstrate the equivalence of a symmetrical system of stays and a concentric load equal to the sum of the stay-loads. Loads of 5 tons were applied in turn at E, F, and D in Fig. 11. A 5 ton uniformly distributed load was also applied along the circle passing through these points. This circle has a radius equal to one-half of the support-circle radius. Deflection traverses were taken along the axes of symmetry and along a diameter at 45 deg. to these axes.

The results of these tests are shown in Fig. 12(*a*) to (*c*). These show clearly that due to the two-pass drilling pattern, the plate does not behave isotropically in respect to single loads but the differences in corresponding deflection traverses for the three loading points are not very great. In Fig. 12(*d*) to (*f*), traverses for symmetrical combinations have been computed from Fig. 12(*a*) to (*c*) by the principle of superposition. It can be seen how closely these combinations approximate in their effect to a 5 ton concentric load. In Fig. 11 it can be seen that the bridge of undrilled metal is relatively wide compared with the dimensions of the drilled areas. This bridge is obviously stiffening the plate along this diameter and deflections due to stay-combinations in Fig. 12(*d*) to (*f*) seem to be 10 per cent. lower than expected from the theory developed above. Where bridges of this nature are relatively narrow, as is often the case in large tube-plates, their effect would probably be much less. This point is well supported by the results of tests on the tube-plate in Fig. 1(*b*) which are reported in a later section of this article. The plate behaved like a continuously drilled, rather than a two-pass, tube-plate.

The assumption that a constant ρ for non-continuously drilled tube-plates can be replaced by more rigorous treatments is to be discussed by the author.[7]

To be continued

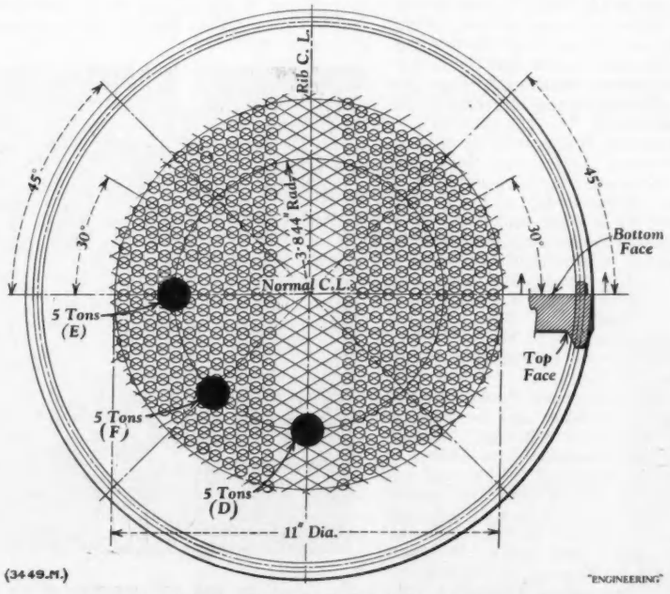
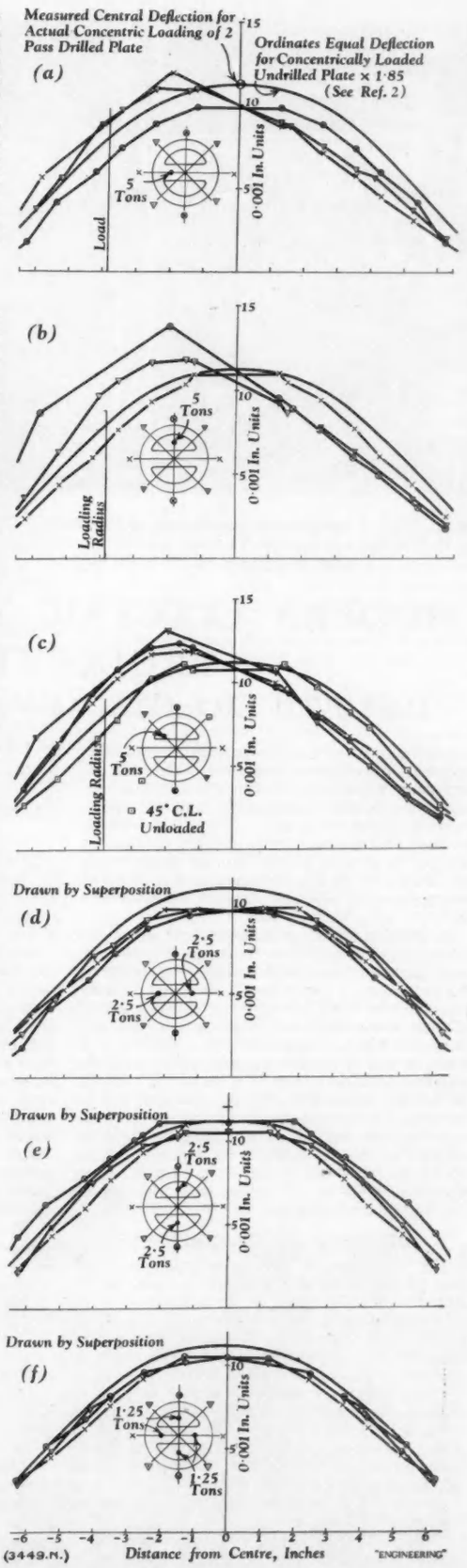


Fig. 11 Model tube-plate tested by eccentric loading.



Details of the tube plate investigated in these tests may be found in Reference 2.

Fig. 12 Deflection traverses in tube-plate of Fig. 11, comparing computed values with measurements made by direct experiment.

Fig. 1 View of main transformer shop at the Walton-on-Thames works of the Hackbridge and Hewittic Electric Co. Ltd. In the foreground are two large vacuum and air treatment autoclaves.

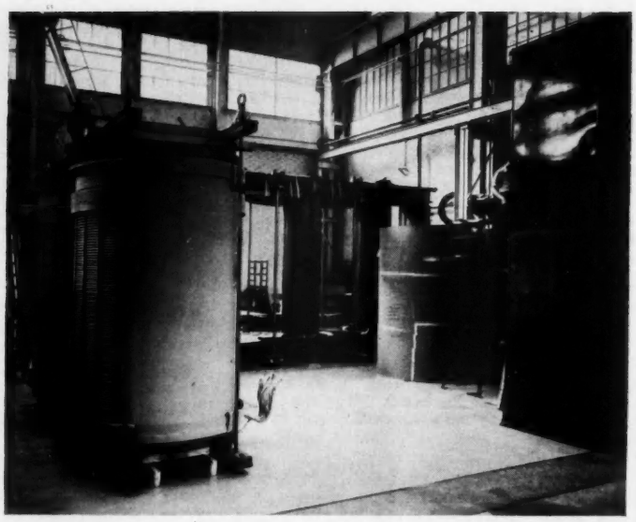


Fig. 2 Part of the screened-off portion at the end of the main transformer shop where very high voltage transformers are assembled, showing a 120 MVA, 275 kV unit.

MODERN ELECTRIC TRANSFORMER PRODUCTION

IMPROVED FACILITIES AT WALTON-ON-THAMES

It is some indication of the growing demand for electrical distribution equipment and of its increasing capacity that the Hackbridge and Hewittic Electric Company, Limited, have found it necessary to make four major extensions to their transformer and rectifier works at Walton-on-Thames since 1950, the result being that since 1925 the floor area has been quadrupled and the number of employees has increased tenfold.

In carrying out the latest extensions particular attention has been paid to the organisation of the manufacture of very high voltage transformers. An extension of the main shop, which is illustrated in Fig. 1, has been devoted to the assembly of these units, while coil winding is carried out in screened bays. Two 120 MVA, 275 kV transformers are at present in production in these departments one of which is shown in Fig. 2. A further extension will be devoted almost exclusively to the winding and erection of rectifier transformers, while the works boilers, which are capable of raising 40,000 lb. of steam per hour at a pressure of 100 to 120 lb. per sq. in., have been converted to oil firing, thus assisting in solving the dust problem.

RELIEVING WORK STRESSES

For constructing the transformers a good deal of new winding machinery has been introduced at Walton, many of the larger units being of the company's own manufacture. The cores are built up from either hot rolled silicon steel laminations or from cold reduced anisotropic material. To obtain the best performance from the latter the work stresses produced in its grain structure during the fabrication of the lamination must be relieved. To meet this requirement an Efco annealing furnace is therefore being installed which will permit the stress relieving of 20 tons of steel per week at a maximum temperature of 850 deg. C. in a controlled atmosphere of nitrogen.

This plant incorporates two electrically-heated hearths, each of which can accommodate a charge of 5 tons; and a muffle for holding each charge in the nitrogen atmosphere. Continuous operation is obtained by alternately charging the two hearths by transferring an electrically heated bell at the completion of the heating and cooling cycle. Fully automatic temperature control equipment is provided, while the atmosphere plant is of the cracked and burnt ammonia type, which incorporates an activated alumina gas drier.

ASSEMBLY ARRANGEMENTS

Special cradles are employed to avoid straining the laminations when the larger cores are being lifted into the vertical position. Each winding is braced radially from the core by packing strips, which form the vertical oil ducts. The pressboard spacers which provide the horizontal oil ducts and the end insulation are treated before use to prevent shrinkage; and an equal amount of ultimate shrinkage is obtained in each winding by proportioning the conductor insulation. Axial clamping pressure is exerted evenly by top core clamping frames, which pull down on to a common mild steel end ring. This ring, in turn, clamps the windings on to the bottom frames. The mechanical support of the windings is designed to withstand the electromagnetic forces resulting from the peak asymetrical short-circuit currents that occur when the only limiting impedance is that inherent in the transformer itself.

The dielectric circuit is designed so that an adequate ratio of stress to strength is maintained in all parts for both power frequency and impulse voltage stressing. Stress control in the form of electrostatic shielding is employed when necessary, and all the major insulation to earth includes the requisite amount of solid insulation which is placed normal to the electrostatic field, thus obviating the weaknesses and inefficiencies of long unbroken surface paths. The core and coil assembly of a modern 15 MVA 33/11 kV transformer in course of construction in the works is illustrated in Fig. 3.

Modern testing requirements necessitate that during manufacture moisture and air must be removed from transformer windings. The oil must also be dried, de-aerated and filtered so that all fibrous and suspended foreign matter is removed and the maximum dielectric strength is achieved. To fulfil these aims a drying oven, which is capable of accommodating the largest transformers in their own tanks, has been installed at Walton-on-Thames, in collaboration with the General Engineering Company (Radcliffe), Limited. Associated with this oven is de-aeration equipment for treating the oil prior to its use in impregnating the transformers, and ancillary gear for automatically controlling the temperature.

With this plant the core and coil assemblies can be completely dried out before impregnation and the transformers can be cooled off and prepared for assembly in their tanks in a controlled atmosphere, thereby reducing to a minimum the time of exposure to the shop surroundings. The oil in the reservoirs is also de-aerated and maintained in a heated condition under vacuum ready for use, and the movement of units into and out of the oven is facilitated. Actually, conveyance between the erection shop, oven and impregnation plant, testing departments and dispatch is effected by an overhead crane and two hydraulically propelled bogies. These bogies, one of which is shown in Fig. 4 transporting a 45 MVA transformer into the drying oven, run on flush-mounted floor rails.

HOT-AIR SUPPLY

The oven chamber, which is also illustrated in Fig. 4, is 37 ft. 6 in. long by 26 ft. 6 in. wide by 24 ft. high. It is insulated with glass-fibre on the walls and ceiling and is lined with sheet aluminium. It is closed by a sliding wall, which is sealed in the closed position and

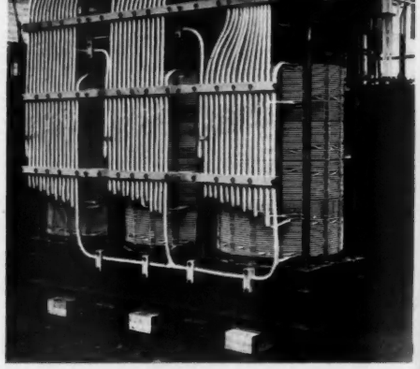


Fig. 3 Core and coil assembly (high tension side) of a modern 15 MVA, 33/11 kV transformer.

incorporates sight windows and a wicket door. The main hot-air supply is circulated from overhead blowers through ducts in both side walls, so as to give an uniform distribution of temperature. Auxiliary air supplies are obtained and connections to the vacuum and oil systems are made through flexible hose. Measuring, control and recording instruments, as well as electronic oil level indicators and a protective alarm, are mounted on a central platform outside the oven.

Oil is stored in three 10,000 gallon tanks, one for raw and two for treated oil. The latter are supplied from the former through a filter, calorifier and de-aerator where the oil is atomised under high vacuum. The maximum surface area for the extraction of moisture and air is therefore exposed until the highest possible dielectric strength has been reached.

The vacuum plant comprises three pumps of the gas ballast type, which are connected so that vacuum can be established either separately or collectively on the oil reservoirs, de-aerator or transformer under treatment. A water-cooled condenser is incorporated in the vacuum lines for the extraction and measurement of water and the collection of gas condensate. The efficient operation of the pumps is thus ensured and an indication of the progress of the treatment provided.

DRYING PROCEDURE

When the core and coils have been placed in the drying oven, air from external steam/air heat exchangers is circulated through it so that the temperature is raised to 150 deg. C. Thereafter the steam heating is automatically supervised to control the speed of evaporation, an important consideration in avoiding deleterious effects on the insulation and the oxidation of metal parts and cores. To prevent a progressive rise of relative humidity a proportion of the moisture-laden air is allowed to escape into the external atmosphere and is replaced through filters by an equivalent intake from the factory. The temperature dispersion factor, insulation resistance and the percentage relative humidity of the atmosphere in both oven and factory are recorded continuously, the combined results of the readings after about 24 hours being used to indicate whether the bulk of the moisture content has been dissipated and if the next stage of drying should commence.

During this next stage the relative humidity of the oven is gradually reduced to a dew point equivalent to a vapour pressure of about 0·5 mm. absolute. To bring about this condition the intake dampers through which factory air is supplied to the oven are closed and the main air circulating system, giving 20,000 cub. ft. per minute, is boosted by a secondary air stream of 2,000 cub. ft. per minute, which is augmented by a dry air supply, the total flow being maintained at a temperature of 105 deg. C. While the intake of dry air continues a corresponding amount of air is allowed to escape to the atmosphere. The low dew point of the dry air supply is maintained by two automatically controlled absorption towers. Finally, the core and coil assembly are cooled off in a controlled atmosphere, so that the unit can be placed in its tank. For this purpose it has to be removed from the oven, but the time during which it is exposed to shop atmosphere is reduced to a minimum.

When it has been assembled in its tank the transformer is returned to the oven, connected to the external process plant by flexible hose and sealed for full vacuum tightness. Hot air is then circulated within the transformer which, combined with the air circulating within the oven, raises the internal temperature to 70 deg. C. To reduce the humidity, dry air is injected into the tank and a corresponding quantity allowed to escape, so that the circulation becomes progressively drier until the required optimum condition of insulation has been reached. This process cycle terminates under a vacuum of 0·1 mm. absolute and the necessary quantity of de-aerated oil to ensure impregnation of the insulation is then transferred from the storage reservoir. Any traces of air which may have remained in the insulation after impregnation are removed by the avidity of de-aerated oil for air.

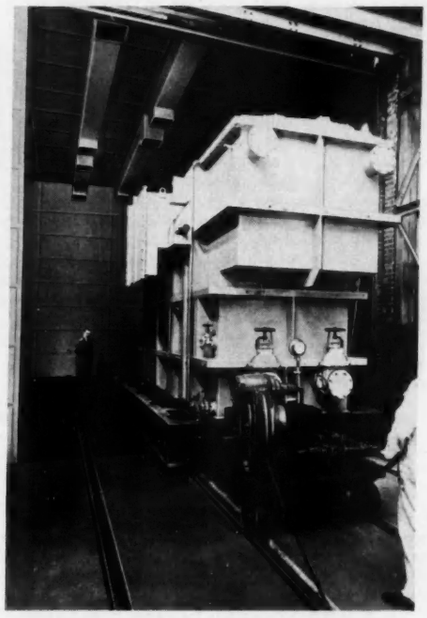


Fig. 4 General view of the drying oven, showing a 45 MVA transformer being removed on an hydraulic bogie.

The space above the oil level in the tank is now returned to atmospheric pressure and the transformer is rapidly cooled by using the air circulating system in the oven. This cooling causes the oil to circulate and accelerates its re-absorption of air at surface level until it has regained its normal quota, the arrangement being such that only dry air is re-absorbed. At the conclusion of the cooling period the transformer is withdrawn from the oven for the assembly of bushings and other auxiliary fittings.

FINAL OIL TREATMENT

Flexible connections to an associated service point are now used to supply dry air at 105 deg. C. to eliminate any moisture absorbed while fitting the bushings. The transformer is then connected to the treated oil reservoir and the oil raised under vacuum to the correct level. Finally, oil is pumped round a circuit comprising the transformer, the filtration plant, calorifier and de-aerator until it has regained its original degassed state and the mature electrical strength of the insulating materials has been obtained. At the same time any fibrous material from the core and windings, which may have become suspended in the oil, will have been removed.

SURGE GENERATOR EQUIPMENT

As part of the re-organisation to which we have drawn attention above, the surge generator equipment in the works has been moved to more spacious quarters and its capacity has been increased to over 2,000 kV, so that impulse tests can be carried out on transformers up to the 400 kV system voltage class.

The generator, which can be seen in the general view of the laboratory given in Fig. 5, comprises 12 stages each of which consists of an oil-filled capacitor with the usual front, tail and charging resistors and adjustable gaps. The 12 gaps are adjusted simultaneously by an electric motor. The spacing control is calibrated in kilovolts and adjustments can be made while the capacitors are being charged up. The step-up transformer has a peak voltage of 100 kV at 50 cycles and a voltage-doubling selenium rectifier gives direct current at 175 kV for charging the 12 sections of the generator in parallel. When the system is triggered all the gaps spark over and the capacitors are temporarily connected in series to give a peak voltage of 2,100 kV when set for the maximum surge. When the capacitors have been charged to the requisite voltage the surge is released by energising a separate small transformer which breaks down the bottom gap. This instantaneously triggers off the complete series of spark gaps. At the same moment an impulse is transmitted to the oscillograph and the " X " sweep is released to make the photographic record.

A piece of equipment, which has been produced in the company's research laboratories, is a recurrent surge oscillograph. This consists of a surge generator and an oscillograph mounted as one unit, and by predicting the impulse distribution assists in locating any weakness which might be prejudicial to the success of the test. Actually the surge generator produces a voltage of identical wave form to that used for impulse testing. Whereas, however, the latter is an instantaneous " shot " of about 750 kV the recurrent surge is only at 150 or 300 volts. As it recurs at a frequency of 50 times per second it can be seen as a steady record on the viewing screen of the oscillograph and can be recorded with the comparatively simple photographic apparatus available. In addition, the equipment can produce a " chopped wave " to simulate the most stringent part of the full impulse test. The oscillograph is provided with timing waves and a range of sweep speeds between 0·5 and 150 microseconds, while the generator can be adjusted to produce any desired waveform. The equipment is therefore valuable both for routine and test purposes.

Other extensions to the works have provided accommodation for an assembly bay for large power rectifiers and a re-arrangement of the medium and low power sections. The rectifiers

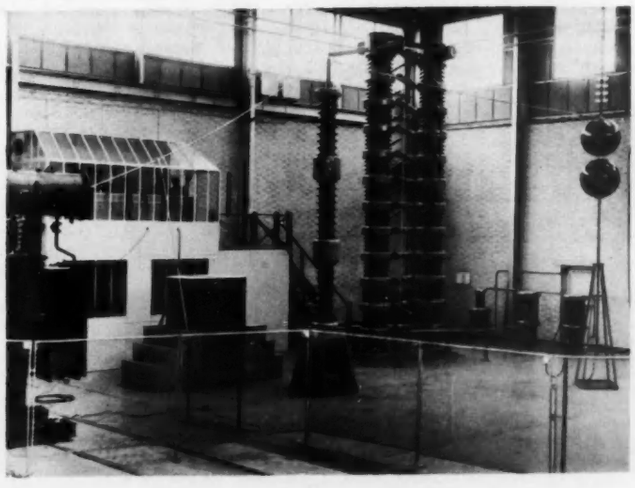


Fig. 5 In the impulse test laboratory the surge generator has a peak capacity of 2,100 kV, developed from 12 stages.

are constructed on a unit basis and modern production methods have been introduced to speed up assembly and dispatch. As regards design all the auxiliary components are now housed in a sheeted angle iron base which forms a compact sub-unit. The rectifier bulbs are grouped in cradles, which slide into tracks on the base to form the necessary enclosure for their ventilation and protection. These cubicles may be arranged in a variety of ways to make the most effective use of the available sub-station space.

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FERGUSON "35" TRACTOR

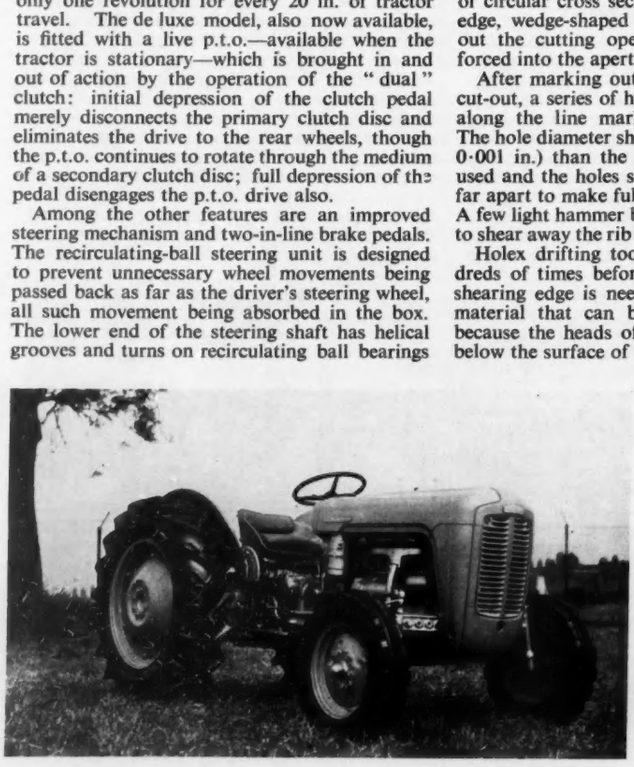
Live P.T.O. Fitted

The mechanisation of farming has been taken a stage further by the Ferguson 35 tractor. After nearly a year's trial in Canada and the United States—and available to those with the necessary dollars—the new machine is now going to be made in Coventry for the sterling area countries. It is to be built by the Standard Motor Company, at their Banner-lane works, immediately at the rate of 100 units per day but quickly rising to 250 units per day. Sales and manufacture overseas are, of course, to be handled by the Massey-Harris-Ferguson organisation.

Slightly larger than its predecessors and with increased power—37 b.h.p. from the Diesel, petrol or vaporising oil models—the new tractor possesses several features not fitted hitherto. In addition to the draft control and the ability to lift and lower implements, the improved hydraulic system possesses the benefit of improved position and response control of the implement. The provision of an epicyclic reduction gear (4 : 1) unit doubles the effectiveness of the gearbox, with its three forward and one reverse gear, to give six forward and two reverse gears. The forward gears include a "creeper" gear giving a speed of just under 1 m.p.h. at 1,500 r.p.m. engine speed, while "top" gives a maximum of 14 m.p.h. at 2,000 r.p.m. There are also two different power take-off speeds: at engine speed for such jobs as mowing, baling, combining, etc., or a ground-speed (slow) p.t.o. for hay-making, planting, fertilising and so on. With this latter arrangement, the p.t.o. shaft makes only one revolution for every 20 in. of tractor travel. The de luxe model, also now available, is fitted with a live p.t.o.—available when the tractor is stationary—which is brought in and out of action by the operation of the "dual" clutch: initial depression of the clutch pedal merely disconnects the primary clutch disc and eliminates the drive to the rear wheels, though the p.t.o. continues to rotate through the medium of a secondary clutch disc; full depression of the pedal disengages the p.t.o. drive also.

Among the other features are an improved steering mechanism and two-in-line brake pedals. The recirculating-ball steering unit is designed to prevent unnecessary wheel movements being passed back as far as the driver's steering wheel, all such movement being absorbed in the box. The lower end of the steering shaft has helical grooves and turns on recirculating ball bearings within a special nut; rotation of the steering wheel, and shaft, forces the nut either up or down the shaft and in so doing actuates the left or right-hand steering assemblies. The pedals for both brakes are located together, adjacent to the driver's right foot. They may be operated together or independently, but a small catch is fitted which enables both pedals to be locked together to ensure even braking when required.

Although designed and marketed primarily for agricultural uses, the Ferguson 35 is suited to general-purpose work, including construction work; in particular, the implement pads are well located for attaching an overload bucket or dozer blades. Furthermore the p.t.o. can be readily adapted to such needs as driving a post-hole digger, compressor, saw or winch.



The Ferguson "35" incorporates a number of innovations over its predecessors, particularly in the transmission system. Two speeds are available at the p.t.o. shaft which, on the de luxe model, can also be live when the tractor is stationary.

★ ★ ★

DRIFTING TOOLS FOR METAL CUTTING

Simple Technique

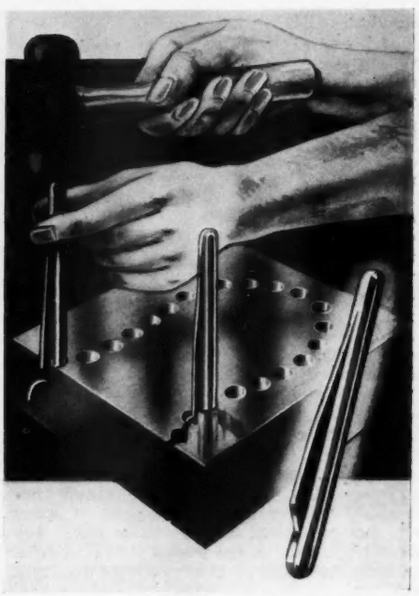
A new simple cutting technique, based on the use of drifting tools, particularly useful for the small workshop and for use in the field has been developed in Switzerland by Holex-Werkzeuge, Berne. Holex tools are distributed in the United Kingdom by Trend Industrial Equipment Limited, 5 The Ridgeway, Stanmore, Middlesex.

The tools are designed to enable an operator to cut out, by hand, sections of mild steel, cast iron or non-ferrous metal, in thicknesses from 16 s.w.g. up to 6 in. By hammering the tools into the material through pilot holes drilled for the purpose, cut-outs can be made by an unskilled operator, dispensing with expensive equipment such as sawing machines and oxy-acetylene burners. Mobile workshops unable to carry any heavy machinery should find these tools invaluable.

Holex tools are supplied in sets of five, different sizes being provided for varying thicknesses and class of material. They are manufactured from durable hard steel. The diameters at base end of the tools range from $\frac{5}{16}$ in. to $\frac{7}{16}$ in., and the lengths range from $2\frac{1}{4}$ in. to 4 in. They are of circular cross section except for a projecting edge, wedge-shaped and tapered, which carries out the cutting operation when the tools are forced into the apertures.

After marking out the shape of the proposed cut-out, a series of holes is drilled close together along the line marked out for that purpose. The hole diameter should be a little larger (about 0·001 in.) than the diameter of the tool to be used and the holes should be spaced sufficiently far apart to make full use of the projecting edge. A few light hammer blows are all that is required to shear away the rib or bridge between the holes.

Holex drifting tools can be used many hundreds of times before a light regrinding of the shearing edge is needed. The thickness of the material that can be cut is almost indefinite because the heads of the tools can be punched below the surface of the material.



Holex drifting tools enable sections of mild steel, cast iron or non-ferrous metal in thicknesses from 16 s.w.g. to 6 in. to be cut out by hand. The tool, which has a tapered cutting edge, is hammered into the material through drilled pilot holes.

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"MEMOMOTION"

A New Work-Study Technique

A new type of cinematography, known as Memomotion, has recently been developed by E.I. du Pont de Nemours and Company, Wilmington, Delaware, U.S.A., for the analysis of processes and techniques in business and industry. Unlike conventional "time and motion" studies, which involve continuous cinematography with many exposures per second and so produce the effect of slowing down the operation to be studied, Memomotion only uses intermittent exposures to condense the action and to allow the projection of the film produced either at normal speed or frame by frame.

The system is operated by placing a cinematograph camera at a key point and exposing the film at intervals ranging from one frame every 20 minutes to one every second, depending on the work that is being studied. Associated with the camera is a 100 ft. film chamber, a device for altering the number of exposures and a solenoid-operated timer control.

If the process under study is photographed at, say, the rate of one frame per second and projected at the normal speed of 16 frames per second not only can an hour-long operation be reviewed in less than four minutes, but as the system emphasises important steps rather than details, rapid visual analysis is possible. There is also a considerable saving in the cost of the film. Projection may, of course, be slowed down or stopped as desired. The availability of very fast film, such as Du Pont's type 931 high-speed rapid-reversal panochromatic, enables the unit to be operated without special lighting.

The new technique has already been used to analyse office procedure, for training employees, for establishing and maintaining quality control, for reducing waste in materials handling and even to improve the design of equipment.

★ ★ ★

We have now been informed that Docker Brothers, Rotton Park-street, Birmingham, 16, co-operated with Lewis Berger and Sons, Limited, in the installation of the flow-coat paint system at the Nacton Works of Ransomes, Sims and Jefferies, Limited, described in our article of September 14 (page 342).

Book Reviews

REACHING THE FARMER

Farm Electrification. By ROBERT H. BROWN. *McGraw-Hill Book Company, Incorporated, 330 West 42nd-street, New York 36, N.Y., U.S.A.* (7 dols.); and *McGraw-Hill Publishing Company, Limited, 95 Farringdon-street, London, E.C.4.* (52*s.* 6*d.*)

It is difficult to realise that only 20 years ago, in spite of the enthusiasm of the pioneering electrical undertakings with large rural areas and of a few manufacturers, the part played by electricity in British agriculture was so small as to be almost insignificant. In 1936 the number of farms with a public electricity supply was under 30,000 and the average annual consumption was well under 2,000 kWh. The number now connected exceeds 200,000 (the latest published figures are 172,542 in England and Wales and 3,971 in Scotland and the rate of connection is about 18,000 each year. These totals represent over 60 per cent. of the farms in England and Wales and some 50 per cent. in Scotland. The increase in annual consumption, too, is noteworthy; it is now a little over 5,700 kWh in the C.E.A. area and no less than 3,530 kWh in northern Scotland.

The reasons for this progress in farm electrification are clear enough. On the farms a rapid increase in the degree of mechanisation has been brought about by the urgent demand for food during the war and by labour shortages which still continue. Electricity is a great help in performing efficiently and cheaply much of the work, and the heating and lighting, in the dairy, poultry houses and farm buildings, while it provides amenities in the homes of the farm workers—an important factor in holding people on the land when the towns offer so many apparent advantages. This advance has been due primarily to the policy of the nationalised Electricity Boards, who were charged with the task of spreading the supply as widely as possible in the rural districts. But if electrification is to be economic, an adequate return on the capital expended must—at least eventually—be forthcoming. The present average cost of connecting a farm to the supply can be taken as about £350, on which the total annual return, for economy, should be about 20 per cent. This means an annual revenue, per farm, of £70 and, at the present average charge per kilowatt-hour of 1·50*d.*, the annual consumption should therefore be rather more than 11,000 kWh as against the present 5,700 kWh or less.

The discrepancy between the actual and "target" consumptions explains the efforts made by the electricity suppliers to encourage fuller use of the service for power loads rather than allowing advantage to be taken of it solely for lighting and domestic purposes which call for only low consumptions. Thus we have agricultural development officers attached to most of the Area Boards, and publicity in many forms given by them, and by the Electrical Development Association, to applications of electricity in agriculture and horticulture. Again, research to ensure that new applications shall be both satisfactory and economical to the farmer and acceptable by the supply authority is done by the rural electrification department of the Electrical Research Association. The most important uses of electricity on the farm are for the driving of barn machinery, milking machines and dairy sterilising, for crop drying and poultry keeping and, in horticulture, for soil warming, glasshouse heating and artificial illumination.

This, in outline, is the present position in Britain. Professor Robert H. Brown of the University of Georgia, the author of this book, gives us an opportunity to make some comparison between British and United States practice. Thus, at the end of 1953, 92·8 per cent. of the 4,992,000 farms in the United States were connected to power lines, as compared with only 10 per cent. in 1934. The author states that the "amount of electricity used on farms" has doubled every four or five years, although the present average consumption is not given. Apparently, the average cost of electricity is just under 3 cents (2·6*d.*), which is almost twice ours. Making allowance for the differences in the crops grown and in farming methods, the American applications of electricity on farms are much the same as in this country, but we should consider their soil-warming practice as rather out of date; it does not appear to include low-voltage warming through a transformer supplying a bare-wire heating circuit, nor is the "dosage" method, omitting a thermostat in frame hot-beds, mentioned. But the book is well produced and illustrated, and clearly written. It contains much useful information in the form of tables of power requirements and energy consumptions for a very wide range of applications. It is intended primarily for agricultural students, and about half of the chapters are devoted to the explanation of electrical principles, wiring methods and the planning of farm electrical installations. One admires the clarity of the author's expression and the way in which he avoids complicating the text by the inclusion of detailed discussion of electrical theory, while maintaining accuracy in his treatment of the essentials.

Presumably because of the differences between the organisation of electricity supply in the United States, as compared with ours, the sizes and operating methods on their farms, and the greater distances from electrical contractors' premises, it would seem that a much greater interest in the details of the wiring installation is expected. Mention is sometimes made of "home-made" equipment whereas we tend to discourage this, particularly on the grounds of safety. Inevitably all the illustrations and descriptions are of American equipment. There are good chapters on water supply and refrigeration but it is disappointing to find only four pages dealing with crop conditioning, a subject on which there is much experience in the United States. Perhaps it is too much to expect in a book of this kind, but it would have been helpful if references to American publications covering the subject matter, especially of the later chapters dealing with electrical operations on the farm, could have been given.

Nevertheless, it is a useful and timely book which will be of great interest to those concerned with the application of electricity to farming.

* * *

TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Heating Plant and Oil-Refuelling Systems. THE DOWSON AND MASON GAS PLANT CO. LTD., Alma Works, Levenshulme, Manchester, 19. (*a*) Car-bottom or bogie furnaces for tempering, stress-relieving, annealing, normalising and hardening operations. Typical installations and particulars of dimensions. Illustrated brochure. (*b*) Diesel oil-refuelling systems for trawlers and road vehicles, dock-side and garage installations. Leaflet. (*c*) Tanks for heating liquids for de-greasing, oil-blending, and melting, heating and boiling operations, designed for exterior or immersion heating by gas or for use with steam coils or electric immersion heaters. Illustrated brochure.

"Aus Produktion und Entwicklung." ALLGEMEINE ELEKTRICITATS-GESELLSCHAFT, 150, Hohenzollerndamm, Berlin-Grunewald. Details of the company's production activities during the past two years covering the equipment manufactured for the generation, transmission and distribution of electricity as well as for its utilisation in industry, in transport, for ship construction and for domestic purposes. A special section is devoted to measuring and controlling apparatus and to laboratory equipment. A fully illustrated book in German with numerous coloured plates.

Air-Break Switchgear. ENGLISH ELECTRIC CO. LTD., Queen's House, Kingsway, London, W.C.2. Air-break switchgear for use in applications up to 600 amperes at 660 volts alternating or direct current, where repeated operations and limited maintenance are required. Single, double or triple pole units with rupturing capacities of 15 MVA or 25 MVA at 400 volts, according to British Standards. Technical details. Illustrated brochure SG/333.

P.V.C. Fans. KEITH BLACKMAN LTD., Mill-Mead-road, London, N.17. "Tornado" centrifugal fans made in P.V.C. for fume removal. Series 1 from 50 to 2,500 cub. ft. per min.; series two, 2,000 to 40,000 cub. ft. per min. (both described in leaflet No. 33) and bifurcated types with capacities from 500 to 4,000 cub. ft. per min. (leaflet No. 34).

Inverse Time Over-current Relays. ENGLISH ELECTRIC CO. LTD., Queen's House, Kingsway, London, W.C.2. Reprint of an article showing how the demands for minimum time over-current relays with improved accuracies and with time/current properties, more closely matching the thermal characteristics of the equipment to be protected is being met. Publication MS/3813.

Control Boards. ENGLISH ELECTRIC CO., LTD., Queen's House, Kingsway, London, W.C.2. Illustrated brochure describing the build-up of control and relay board. A unit system employing a new design of cubicle, the parts of which are completely standardised. A wide variety of panels is available. Publication SG/229.

Steam Generating Plant. MITCHELL ENGINEERING LTD., 1 Bedford-square, London, W.C.1. Water-tube boilers for steam raising; single and multi-drum units. Evaporative capacities up to 860,000 lb. per hour using fuels ranging from sawdust to asphalt. Drawings, illustrations and some particulars given in Report No. 5.

Pile-Driving Equipment. WOODFIELD HOIST AND ASSOCIATED INDUSTRIES LTD., Frindsbury Works, Rochester, Kent. Pile-driving equipment for sale or hire, including tower frames, hanging leaders, steam boilers, Diesel engines, winches, etc. Illustrated booklet.

Superheaters. NORTH EASTERN MARINE ENGINEERING CO. LTD., Wallsend, Northumberland. Notes on the types and uses of superheaters, including independently-fired models, with trial figures for two steamships. Booklet S.H.1.

Instrument Charts and Scales. GEORGE KENT, LTD., Luton, Bedfordshire. Tables of standard charts and scales for Multelec instruments. Including thermo-couples, resistance thermometers, pH and gas-analysis instruments. Publication No. 925.

Copper Tubes. IMPERIAL CHEMICAL INDUSTRIES LTD., Imperial Chemical House Millbank, London, S.W.1. Copper tubes for domestic water services. Physical characteristics, fittings, specifications and other data. Illustrated booklet.

Condenser Bushings. ENGLISH ELECTRIC CO. LTD., Queen's House, Kingsway, London, W.C.2. 66/69 kV spring-loaded oil-filled condenser bushings for outdoor oil circuit-breakers. Illustrated leaflet SG/257.

Exhaust Brake. CLAYTON DEWANDRE CO. LTD., Lincoln. Clayton-Oetiker exhaust brake for commercial vehicles using Diesel engines; two sizes. Details of layout, installation and capabilities. Illustrated booklet.

Open-Hearth Furnaces. GEORGE KENT, LTD., Luton, Bedfordshire. Instrumentation and automatic control open hearth furnaces. Descriptions of and comments of six plants now in operation and notes on new developments. Publication T.P. 5006/456.

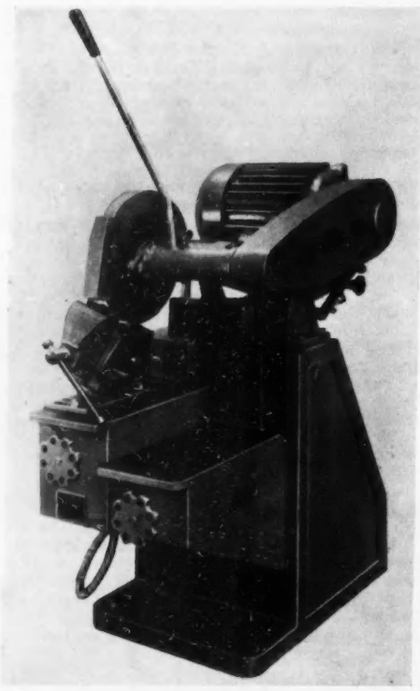
Smoke Meter. A. M. LOCK & CO., LTD. 79 Union-street, Oldham, Lancashire. Smoke meter and alarm system utilising light rays suitable for use with continuous recorder. Leaflet.

Instrument Spare Parts. GEORGE KENT, LTD., Luton, Bedfordshire. Spare parts list for universal pH units (flow and tank type elements) and electrometers. Publication No. 969.

Torque Convertors. NATIONAL SUPPLY CO., Two Gateway Center, Pittsburgh, Pa., U.S.A. Torque convertors for heavy industrial services from 100 to 1,000 h.p. Bulletin No. 468.

Electric Motor Service Centres. BROOK MOTORS, LTD. Empress Works, Huddersfield. "On the Map" a decorated booklet in colour describing the towns in Britain where the firm has service depots.

Dust Collection. DALLOW LAMBERT & CO. LTD., Thurmaston, Leicester. Wet type dust collectors for industrial purposes. Illustrated leaflet.



The Osmond abrasive-wheel cutting-off machine is specially designed for non-ferrous foundries, and has twin work tables which can be used for mounting special fixtures. A swivel vice is also supplied, as illustrated.

PORTABLE HARDNESS TESTER

Improved Indentometer

An improved model of the Indentometer, a portable Rockwell-type hardness tester, has been introduced by C. Tennant, Sons and Company, Limited, 4, Copthall Avenue, London, E.C.2. The modifications have been made in collaboration with the Citroen Company of France, in order to meet the requirements of their many factories.

The Indentometer, which may be used with loads of up to 150 kg., gives readings on the Rockwell "A," "B" and "C" scales. The load is applied through a hydraulic pressure unit of great accuracy. An improved "zeroing" device is now provided to enable variations in atmospheric conditions to be counteracted under all possible circumstances.

A carrying handle has been provided at the point of balance of the instrument to facilitate handling and testing. A new method of mounting the penetrator facilitates changing from the conical diamond to a ball and an improved easy-to-read dial has now been fitted to register the load applied.

A U-clamp, giving facilities for testing objects of up to 5¼ in. thick or 5¼ in. in diameter, is provided as standard equipment with the instrument. A quick release cam mechanism can also be provided if required. In addition, a chain type of clamp may be used for testing large or awkwardly-shaped specimens and an electromagnetic clamp for testing ferrous cylinders, rolls, or large flat surfaces. A new stand has also been introduced, which may be used to convert the instrument for conventional bench testing.

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ABRASIVE CUTTING-OFF MACHINE FOR NON-FERROUS FOUNDRIES

The accompanying illustration shows a machine which has been specially developed by A. and S. Osmond, Limited, Bristol, 8, for medium-sized cutting-off work in non-ferrous foundries. It is capable of cutting 2½ in. diameter bronze in approximately 10 seconds. The cutting member of the machine is an abrasive disc 12 in. diameter and $\frac{1}{16}$ in., $\frac{3}{32}$ in., or $\frac{1}{8}$ in. wide, driven by V-belts from a 7½ h.p. motor. The cutting-off wheel, spindle and motor are carried on a rocking frame of fabricated steel which is, in turn, mounted on a base of fabricated steel or cast iron. A dust hood is provided, with a 4 in. in diameter outlet for connecting to a dust-extraction system, or to a separate unit, which can be supplied as extra equipment if required.

The work is carried on one or both of two work tables, each 18 in. by 9 in., which are arranged for independent, counter-balanced rise and fall, and are locked in position by hand-wheels. This arrangement facilitates the attachment of special fixtures designed to suit particular castings. A screw vice is supplied as part of the standard equipment of the machine. The vice, which is shown in the illustration, is mounted on a swivel base, and can be used to hold a variety of work.

The Mortimer Engineering Company, Limited, 210 Acton-lane, Harlesden, London, N.W.10, are the sole agents for the machine in London and southern England.

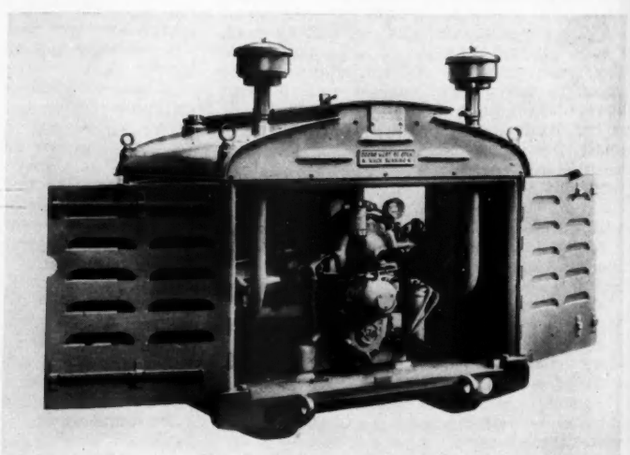
★ ★ ★

AIR-COOLED DIESEL POWER PACK

12·5 *to* 20 *b.h.p.*

The power pack illustrated below is an adaptation of the "Victor Vixen" Diesel engine made by the Coventry Victor Motor Company, Limited, Cox-street, Coventry. The engine is an air-cooled, horizontally-opposed, twin-cylinder Diesel, operating on the four-stroke cycle, and having a bore and stroke of 3·55 in. and 4 in. respectively. It has a power output of 12·5 b.h.p. at 1,250 r.p.m., 15 b.h.p. at 1,500 r.p.m., and 20 b.h.p. at 2,000 r.p.m. There is a mechanical type speed governor. The engine is arranged for cold starting by hand, being provided with "Weaver" patent cold-starting injectors, decompressor and geared starting handle; electric starting equipment is available as an alternative if specially ordered.

In its power pack form the engine is mounted on a fabricated steel baseplate, and fitted with a hinged steel cover, with ventilation louvres in the panels. An extension is fitted to the flywheel shaft at the rear, to drive an external power take-off pulley through a hand-operated clutch. The engine alone weighs approximately 448 lb., and as illustrated the complete power pack has a total weight of 592 lb. It can be supplied with lighter baseplates to reduce the total weight if required; the baseplate shown in the illustration was specially ordered, and weighs 112 lb.



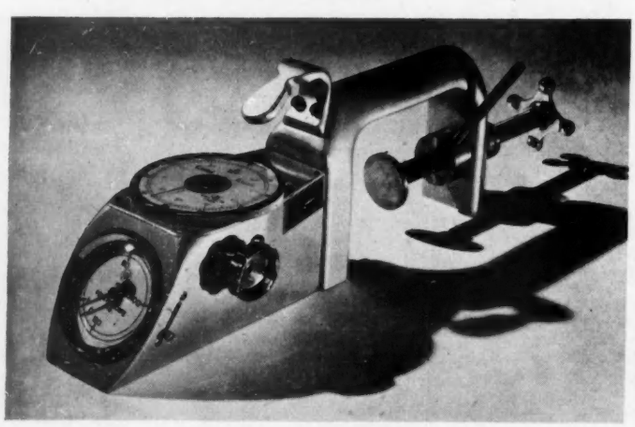
Air cooling, and a power range of from 12·5 to 20 b.h.p., make this Coventry Victor Diesel power pack suitable for many different types of work.

★ ★ ★

"NO-BREAK" POWER PLANT

To overcome the far-reaching consequences of a breakdown in telecommunication systems where the equipment is fed from the public supply, Standard Telephones and Cables, Limited, Aldwych, London, W.C.2, and Pelapone Engines, Limited, Derby, have jointly designed a 55 kVA "no-break" power plant.

This consists basically of an electric motor and alternator, a Diesel engine, a heavy flywheel and a magnetic clutch. The motor, alternator and flywheel run continuously, the motor being connected to the mains and the load being supplied from the alternator. In the event of a main's failure the Diesel engine starts automatically and is coupled by the magnetic clutch to the flywheel and alternator. The energy stored in the flywheel is sufficient to drive the loaded alternator at full speed for long enough to enable the engine to take up the drive.



The load of up to 150 kg. is applied through a hydraulic pressure unit of this hardness tester. The U-clamp provides for testing objects up to 5¼ in. thick. A chain-type clamp is available for large or awkwardly shaped specimens, and an electromagnetic clamp is also available.

CALDER HALL ENGINEERING ELEMENTS

Although the Calder Hall nuclear power station is similar—if its reactors and heat exchangers are regarded as furnaces and boilers—to a conventional thermal plant, it has many unique elements arising from its unusual source of energy. That source is nuclear fission. Thus to the familiar problems of power-station construction, many novel problems have been added. With this in mind, we discuss below some of the station's engineering features, and in so doing amplify the introductory article published on page 418 last week. In the next issue we shall consider contributions made by engineering firms. We begin, to-day with a brief description of the plant and end by tabulating its principal design data.

In the Calder Hall nuclear power station heat is generated in reactors by nuclear fission and carried by carbon dioxide gas to heat exchangers where steam is formed. The steam is delivered to turbo-generators which, when the station is officially opened by Her Majesty The Queen on October 17, will supply power to the national grid. Nuclear fission is the disintegration of atomic nuclei under neutron bombardment. Part of the original mass is converted into energy in accordance with Einstein's formula $e = mc^2$, where e is the resultant energy, m the lost mass and c the velocity of light. This energy appears as the kinetic energy of the fission fragments and other particles, and as radiation. Neutrons are also emitted and these serve to cause fission of other nuclei and so continue the chain reaction. A moderator is used to slow down the neutrons, thereby increasing the probability that a fission reaction will occur. The Calder Hall reactors are graphite moderated and use natural uranium (0·7 per cent. of the fissile isotope uranium 235) as fuel. Neutrons can also convert uranium 238 into fissile plutonium. This is the main purpose of the Calder Hall station, with power as by-product.

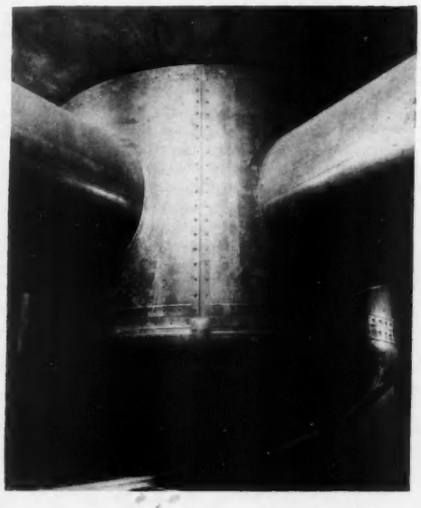


Fig. 2 The carbon dioxide coolant, which is maintained at about 100 lb. per sq. in. gauge pressure, enters the pressure vessel by four inlet ducts, two of which can be seen here.

The reactor core, as can be seen from Fig. 1, is housed in a steel pressure vessel and comprises a graphite structure containing vertical channels into which fuel elements and control rods may be inserted. The graphite rests on flat steel plates set on a steel grid, which is supported within the vessel by its periphery. The fuel elements are rods of natural uranium in magnesium alloy cans. These are cylindrical barrels sealed at one end by a plug and end cap, and at the other by a spacer and end cap, and carry single-start helical fins. The coolant gas, the temperature of which rises by about 200 deg. C. in passing through the core, flows in the annular space between the graphite and the fuel can. The graphite structure consists of a central section containing fuel channels and an outer section, or reflector, designed to limit neutron wastage by scattering them back to the reactor.

The pressure vessel is a cylindrical shell with domed ends, set with its axis vertical, and made of 2 in. thick mild steel. The cooling gas, which is at a pressure of about 100 lb. per sq. in. gauge throughout the circuit, enters the bottom dome by four inlet ducts, as shown in Fig. 2, flows up through the fuel channels, and is led away to the heat exchangers by four outlet ducts situated above the graphite structure. From each heat exchanger it is returned to the pressure vessel by a 1,500 h.p. centrifugal blower. A 7 ft. thick concrete biological shield encloses the entire pressure vessel and is itself protected from radiation and thermal damage by means of a 6 in. thick mild-steel thermal shield covering its inner face.

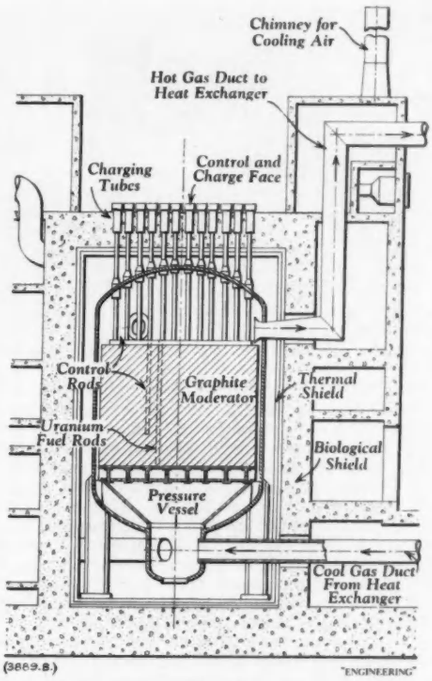


Fig. 1 Layout of a Calder Hall reactor, showing arrangement of graphite moderator and reflector, fuel and control-rod channels, the pressure vessel, and entry and outlet ducts for the coolant gas.

The Calder Hall "A" station includes the following items: 2 reactors, 8 heat exchangers, 8 main blowers, 4 turbo-alternators and condensers, 2 dump condensers and 2 cooling towers.

Civil Engineering

The station to be officially opened on October 17 is known as Calder Hall "A," but since the second station resembles it closely, and is already under construction, we shall refer to both in discussing the civil engineering work. The building and civil engineering contract for the Calder Hall "A" station was placed with Taylor Woodrow Construction, Limited, on July 22, 1953. The main contracting work on the first of the two reactors was finished within 12 months and in spite of bad weather never fell behind schedule. The Calder Hall "A" contract comprised two reactor buildings, 120 ft. high; two cooling towers, 300 ft. high and 200 ft. in maximum diameter; the turbine hall; ancillary buildings; and services, including roads. Important items were two concrete rafts on which the reactor buildings are based, and the octagonal biological shields, which fill the dual role of structural support and protection from radiation. Each of the rafts, which are 130 ft. long and 11 ft. deep, contains approximately 5,600 cub. yds. of concrete and 270 tons of reinforcing steel. Tolerances to within plus or minus 0·1 in. on both vertical and plan true dimensions were required in the erection of the 7 ft. thick reinforced concrete shields, which are 90 ft. high. Great care had also to be taken in the placing of concrete in confined spaces round the numerous charging and other tubes passing through the shields. Further reinforced concrete shielding, in the form of envelope walls about the faces, is embodied in the design, and each shield is covered by

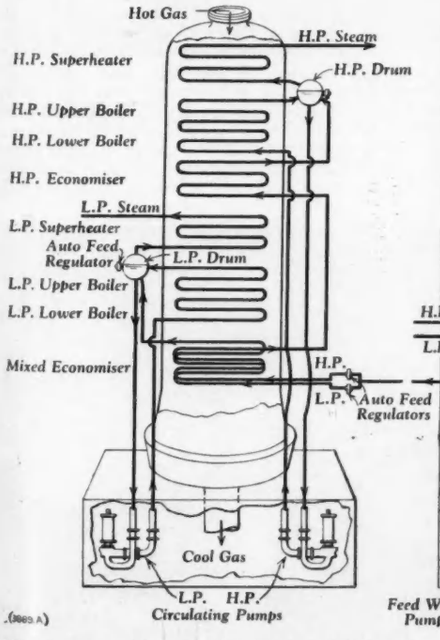


Fig. 3 Flow diagram for Calder Hall heat exchanger. By use of the dual-pressure fuel cycle, increased electrical output and improved control of coolant temperature can be obtained.

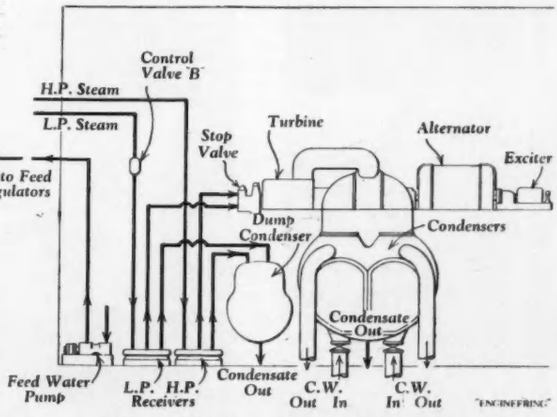


Fig. 4 Turbines and associated plant. The designers of Calder Hall made use where possible of conventional engineering techniques. The turbines are generally of orthodox design.

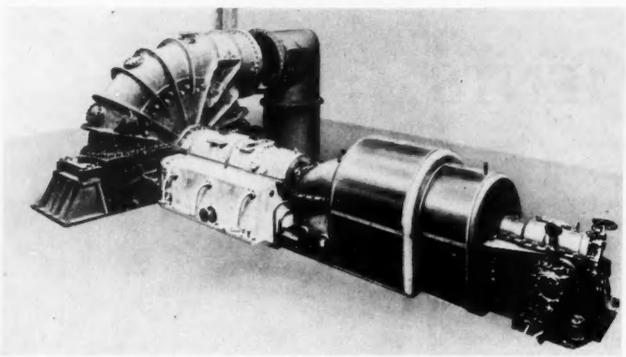


Fig. 5 Control of the coolant mass flow is effected by varying the speed of the centrifugal blowers which circulate the gas through the reactor and heat exchangers. A blower is shown here under test.

an 8 ft. thick reinforced concrete roof slab. For this purpose a concrete of unusual composition was specified.

It was important to ensure that the concrete was of high and uniform density—a minimum of 150 lb. per cub. ft. as against normal requirements of 145 lb. per cub. ft. This was accomplished by strict control in the weighing of all aggregate, sand, cement and water. A wetting agent was used to increase workability with a lower water / cement ratio, and in placing the concrete it was vibrated with internal vibrators. The density achieved was 162 lb. per cub. ft.

Work on the cooling towers was carried out from an internal scaffold of prefabricated steel, so that as progress was made on the first tower, part of the scaffold was suspended from the shell and a start was made on the second tower with the aid of the released lower portion of the scaffold. A rate of one 3 ft. concrete lift a day was reached and maintained. The turbine hall group (including control block, administration buildings and workshops) was constructed on traditional lines with one important exception. Each of the four identical turbine blocks was concreted in one lift. Design and manufacture of shutters of the necessary accuracy, and close liaison by telephone between the various working levels within the shutters and the central control were features of the work.

Construction of Calder Hall "B," identical and adjacent to Calder Hall "A," began in July, 1955, and should be complete by mid-1958, taking only nine-tenths of the time spent on the first station. By this month, the pressure vessel of one reactor should be in place, the roof should be in process of being completed, and the control and blower houses should be clad with asbestos sheeting. In the case of the other reactor, 13 lifts out of the requisite 20 should have been placed for the octagonal shield. The turbine blocks should be complete and the steel frame will be in process of erection; the shell of one cooling tower will be almost finished, and the columns and ring beam of the other will be ready for the shell, which will be finished by June, 1957. When both power stations are completed, they will contain: 130,000 cub. yd. of concrete, weighing approximately 250,000 tons; and 6,000 tons of reinforcing steel bar. The work, which has called for 150,000 cub. yd. of excavation, will have been accomplished within 5 years.

Pressure Vessel

Early in 1951 when the design of the Calder Hall plant was undertaken, it was a major problem to design and construct satisfactorily a pressure vessel of the kind required, and to determine its maximum safe operating pressure. However, the work was undertaken by Whessoe Limited, who had been engaged on a vertical spinning tunnel for the National Aircraft Establishment. This tunnel had many features in common with the proposed reactor vessel, though pressure and temperature conditions were likely to be much more arduous.

The first point settled was the maximum thickness which at that time it was considered reasonable to weld at the construction site to X-ray standards, and this was taken to be 2 in. For the specified vertical cylindrical vessel with ellipsoidal ends this permits a working pressure of about 100 lb. per sq. in. Experience in the welding of thick material in the field in exposed conditions indicated that a specially ductile mild steel was desirable. The steel chosen was one developed specially for such purposes with an acceptable and controlled notch impact value at the lowest temperatures likely to occur during construction. Tests were carried out to determine the degree of corrosion occurring with carbon dioxide in contact with the steel at a high temperature, and examination of the physical properties was also made. An additional test carried out on all the steel used in the vessels was a 100 per cent. examination for lamination using ultrasonic flaw detection.

In addition to the design of a shell to contain the carbon dioxide at the required pressure and temperature, the following major problems arose: the vessel had to be supported in such a manner that the maximum degree of freedom for expansion due to temperature and pressure was permitted; the very heavy graphite core had to be supported within the vessel; and a multiplicity of holes of various sizes had to be provided in the pressure shell. In view of the large radial expansion due to temperature it was not possible to support the vessel on a conventional skirt, and it was decided to use a number of equally spaced peripheral supports in the form of vertical legs. These were designed so that they would separately permit a radial movement, but collectively keep the vessel fixed in space.

The graphite core is supported on a network of deep beams with frequent intersections to form a grid which is bounded on its outer periphery by a circular beam of diameter slightly less than that of the inside vessel wall. This circular beam is in turn supported at points vertically above the external legs so that the loads would be transmitted directly from the shell to the legs below. The effect is to squeeze the shell, rather than adding to the stresses imposed upon it by the internal pressure. This "diagrid" is a highly redundant structure requiring the solution of 35 simultaneous equations to determine the size of beams necessary to support the load within the limit of allowable deflection.

Although all pressure vessels have holes in them, it was not possible to rely on the conventional methods of reinforcement for the large openings, up to 12 ft. in diameter, intended in the reactor vessels. Here experience gained by observing the behaviour of holes in the vertical spinning tunnel became valuable, and results of strain-gauge tests on this vessel under pressure enabled a design to be evolved with confidence.

During construction, five large sections, namely, the bottom dome, the top dome, two parallel cylindrical sections, and the graphite support, were fabricated on the ground and then lifted into position by a 100 ton derrick. Every foot of the welding was examined radiographically to the requirements of Lloyd's Class I standards. After the welding was completed, the vessels were surrounded by thermal insulation and stress relieved. This was carried out by passing a heavy current through an internal network of tubing forming a large heater element with an input of 1·5 MW. These vessels are believed to be the largest to be stress relieved in this way up to the present time. It took several days to reach the soaking temperature. After maintaining this temperature for the necessary time the vessel was allowed to cool slowly. It was decided to test the vessel under air pressure, since it was thought that the use of hydraulic techniques involving a great weight of liquid would have overloaded the structure. Large pressure vessels are conventionally tested under hydraulic pressure to eliminate danger from the large storage of energy in an air test.

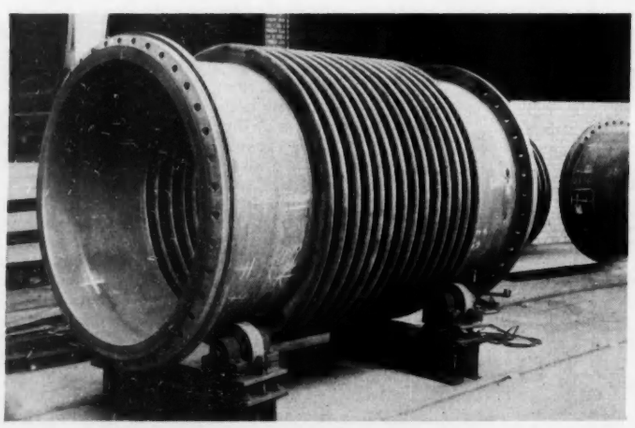


Fig. 6 To obtain the necessary duct flexibility between the reactor, the heat exchangers and the gas blowers, bellows are fitted. Size and pressure required that they should be of tied pattern.

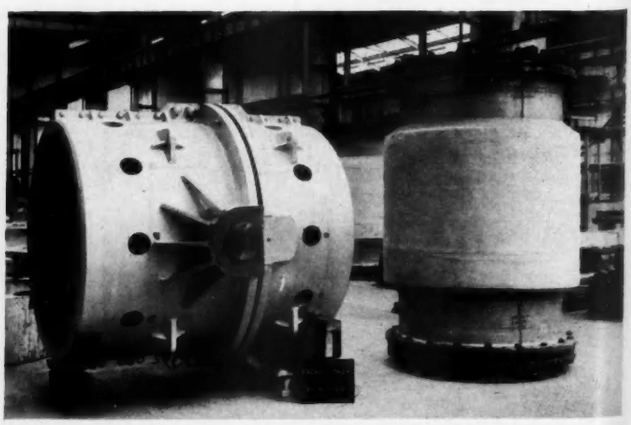


Fig. 7 Bellows assembly. Single-hinge bellows are used where uniplanar deflections are involved and a special gimbal ring type where angular movements occur in two planes.

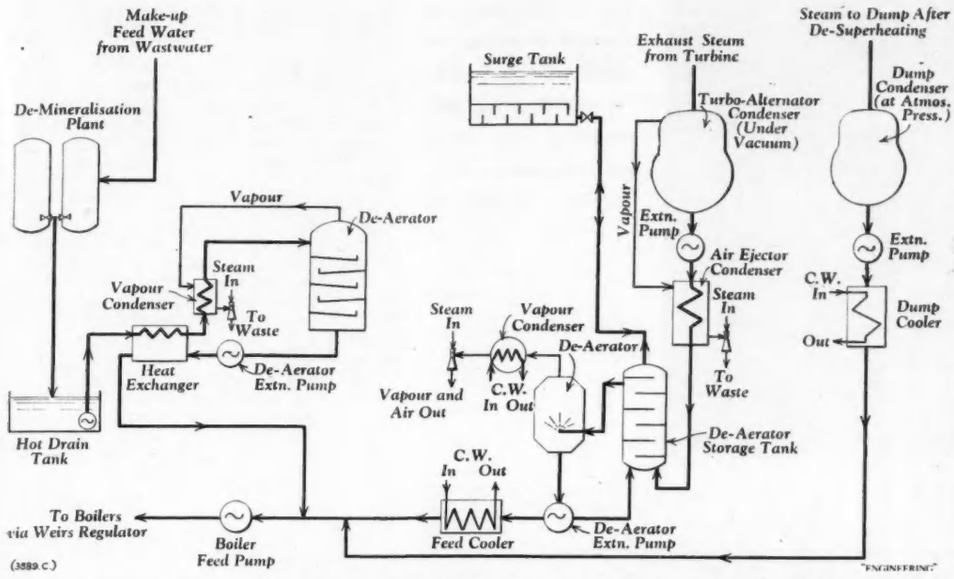


Fig. 8 Feed water system. The low-pressure turbines have twin exhausts which discharge into a surface condenser. The condensate passes through a de-aerating plant and the steam cycle is completed by the high-pressure and low-pressure feed water pumps which return the water to the economisers.

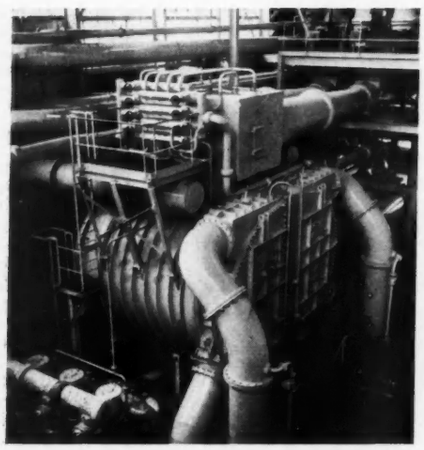


Fig. 9 Dump condenser (No. 1 reactor) into which up to the full-load steam production may be condensed. This is necessary on start-up and shut-down or to permit continued plutonium production without running the turbines.

However, the protection afforded by the heavy concrete radiation shield made it possible in this case to undertake an air test to the full test pressure, of 135 lb. per sq. in. During this test strain-gauge readings were taken on points of interest. A final test was carried out under partial vacuum at one-tenth of atmospheric pressure by means of a large rotary vacuum pump. This is used under operational conditions for exhausting the vessel when charging or changing the coolant.

Heat Exchangers

Steel fabrication played a part too in the construction of the heat exchangers, but these were the responsibility of Babcock and Wilcox Limited. The steam cycle chosen for Calder Hall was the outcome of work which had been undertaken as long ago as 1948. At this time, investigations were made into the use of single, double and triple pressure steam cycles with and without feed-heating, reheating and thermo-compression. The dual-pressure steam cycle, for a modest addition to complexity, gives a gain in electrical output of some 12 per cent. over the best that can be attained with a single-pressure cycle. This is achieved at the expense of considerable additional heating surface in the heat exchangers, but whereas in the case of the single-pressure cycle, the addition of heating surface beyond a certain point is uneconomic, the dual-pressure cycle favours considerably more supplementary heating surface, all of which is in fact useful.

The result, therefore, is that the heat exchangers are large items of plant and have to be designed, at the same time, for minimum draught loss in order to reduce the blower power necessary to circulate the primary coolant. Fig. 3 shows diagrammatically the arrangement of a Calder Hall heat exchanger and its connections to the turbine hall which appears in Fig. 4.

The dual-pressure steam cycle has an additional advantage in that it permits close regulation of coolant temperature in the reactor. This is of major importance as it minimises temperature stresses due to plant changes and such emergency conditions as alternator trip-out. In practice, the low-pressure sections of the heat exchangers are actually operated at variable pressure; they are called upon to steam at their lowest pressure when the load on the station is a maximum and at their highest pressure when the load on the station is a minimum. Under the latter condition of operation, however, the steam pressures in both the high and low pressure sections of the heat exchangers are practically equal to one another. The effect of allowing the pressure of the low-pressure system to increase as the load on the station falls is conveniently to prevent the coolant temperature at the reactor inlet from falling. Associated with variable-speed drive of the blowers, the dual-pressure cycle enables the coolant temperature both entering and leaving the reactor to be maintained constant irrespective of load or, alternatively, to be preset at such other levels as are calculated to minimise transient temperature stresses in the plant.

Calculation of the gas-cooled graphite-moderated nuclear power plant cycle for maximum production of electricity shows that reasonably high steam pressures follow from the adoption of the dual-pressure cycle; for instance, 65 per cent. of the total steam could be generated at a pressure of 400 lb. per sq. in., the rest at 130 lb. per sq. in. At Calder Hall, however, the emphasis is on production of plutonium rather than of electricity and the maximum thermal output from a given investment of fuel is desirable. Accordingly, the coolant temperature rise in the reactor is required to be as high as possible, and this in turn means that the temperature of the coolant leaving the heat exchangers has to be as low as possible, since the upper temperature of the coolant is limited. It is of course possible to obtain this cooling by the addition of an after-cooler, and to accept the waste of heat this method would involve. It is equally possible to obtain this extra cooling by appropriate selection of the dual-pressure cycle steam pressures, a method which does not involve waste of heat. Thus, at Calder Hall the high and low pressure steam is generated at 200 lb. per sq. in. and 60 lb. per sq. in. —the optimum not for maximum station thermal efficiency but for maximum generation of electricity together with maximum production of plutonium.

In the design of the heat exchangers, one matter of paramount importance is to obtain for a given economic expenditure the highest quality of steam with the least possible draught loss. The former requirement necessitates acceptance of very small temperature differences; and it is clear that both these factors inevitably involve using plant of large dimensions. Since the transmission of heat from the coolant side to the steaming side is controlled by the conductance of the gas film, the use of extended heating surface is of course imperative. The choice of surface was limited in the case of Calder Hall rather by the availability of suitable production plant than by theoretical considerations. Also, in view of the small temperature differences involved, it was necessary to ensure that the thermal bond between the extended surface and the parent surface of the pressure parts was of high efficiency. These and similar requirements were met by adopting electrically welded stud tube heating surface.

Another matter of considerable importance in the design of the heat exchangers was to ensure that leakage of steam or water into the coolant was a very remote possibility. A design was evolved, therefore, in which connections such as those between tubes and headers were kept outside the gas vessels so that any leakage which might conceivably occur at these connections would result in escape of steam or water to the atmosphere and not into the coolant. The horizontal multi-loop form of heating surface was chosen, largely because of its inherent flexibility and consequent freedom from stress.

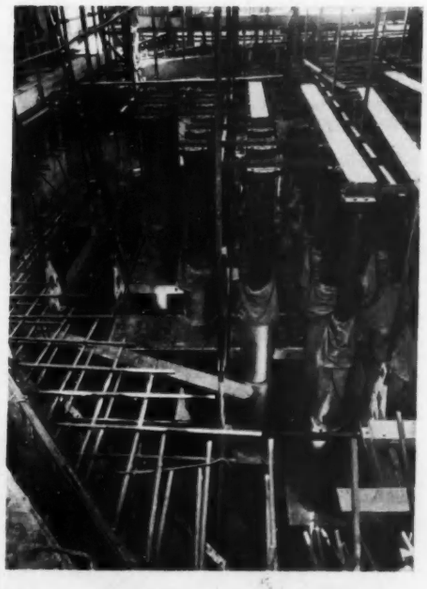


Fig. 10 Header tubes mounted on the upper dome of the pressure vessel, shown during construction. Through these fuel is loaded into the reactor core, each tube serving several fuel channels.

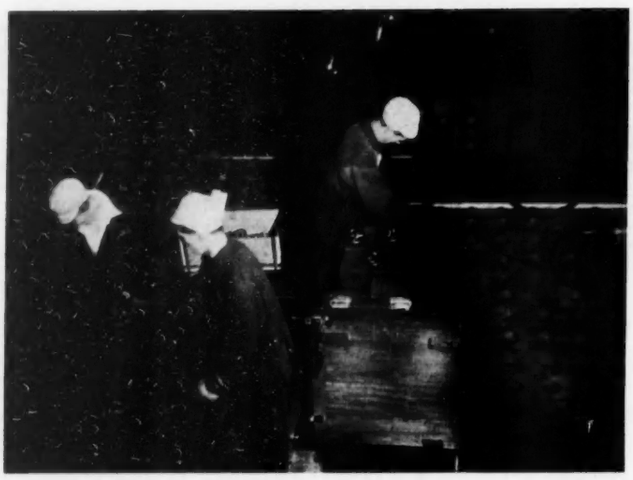


Fig. 11 Cleanliness was essential in laying the graphite blocks forming the reactor core, since impurities may absorb neutrons and so reduce the number available for useful reactions.

Inspection included leakage tests using hydrogen and high-vacuum techniques.

A vertical arrangement was adopted for each of the heat exchangers since this matched the vertical channel arrangement of the reactor and, in addition, permitted the most logical arrangement of the superheating, evaporating and feed-heating sections of the steam raising plant. In external appearance, and in fact, the heat-exchanger shells are reminiscent of oil refinery practice. Each shell was dispatched to the site in a number of completed fusion-welded rings, a pair of completed fusion-welded ends of semi-ellipsoidal profile, and a supporting skirt divided into two halves. All nozzles and branches were already attached. Upon arrival at the site, the pieces comprising each shell were welded together circumferentially. Stress-relieving was carried out by induction heating. Upon completion, each shell was filled with water while still lying on its side and hydraulically pressure tested. The shells were then cleaned to a high standard and sealed with a content of silica-gel before being lifted into position. They were then raised on to their concrete plinths by 100 ton gin poles.

Coolant Circulating Systems

A further section of the Calder Hall station which can be considered separately is the coolant circulating system whereby heat is carried by carbon dioxide gas from the reactors to the heat exchangers. Many of the items have been contributed by C. A. Parsons and Company. Each of the four heat exchangers are connected to the main reactor vessel by 54 in. circular gas ducts and the main circulators are installed in the low-temperature return from the heat exchangers to the boilers. The problems associated with accommodating the thrusts and temperature expansions of this large system are severe, and experience of large, hot interconnecting ducts associated with industrial gas turbines was found to be particularly appropriate.

One of the most important considerations affecting the design of the gas circulators was the speed variation demanded by considerations of reactor control. In general terms the speed of the circulators is determined by the requirement that the gas outlet temperature from the reactor be kept constant. Variations in the division of the steam flow between the high and low pressure sections of the dual-pressure heat exchangers likewise serve to maintain a constant temperature at the circulator inlet. Reactor start-up and part-load conditions require a large variation in the circulator speed and the ability to run at a reduced speed for long periods. While perhaps operation may show it extravagant, it was decided to design for a 10 : 1 speed variation over the working range of the circulator and it seemed that a direct-current motor direct drive operating on the Ward Leonard system would most readily meet the exacting demands imposed.

It was clear that a relatively slow-speed centrifugal blower would best suit the drive conditions, and an overhung design was adopted since one of the most important specification requirements was complete containment of the gas. The speed of the seal surfaces made necessary a " wet " seal, and this in turn imposed the provision that seal oil must not leak into the system either directly or by diffusion. A seal was adopted similar to those developed for hydrogen-cooled alternators. It was specified that the seal should be capable of inspection or removal while the system remained under gas pressure, but with the circulating unit at rest. A standstill seal was therefore introduced between the impeller and the labyrinth gland which could be brought into operation when required, to enable the blower to be rotated at very low speeds and under emergency conditions. For this purpose a pony motor of some 10/100 horse-power is mounted and geared to the impeller shaft. To overcome the risk of the pony motor being driven by the main direct-current motor when the latter is energised, a Sinclair type SS. clutch is incorporated in the gear train. A photograph of the circulator on the test bed is shown in Fig. 5.

To give the necessary duct flexibility between the reactor, the heat exchangers and the circulators, bellows were fitted. Because of the size and pressure involved these were necessarily of " tied " design. A single-hinged type was used for uniplanar deflections, and a special gimbal ring version where angular movements were required in two planes. Many different lay-outs were tried. The final design consisted of two heavy flanges connected by plain rings to the bellows section proper and outlet casings housing the hinge pins spigoted to the bellows flanges. A bellows unit is illustrated in Fig. 6, and Fig. 7 shows a completed assembly. In view of the extremely heavy ducting and the load variations involved, constant support hangers were used instead of standard spring supports, in order to minimise undesirable loading and moments on the reactor.

Turbines

Steam generated in the heat exchangers passes to the main steam turbines, and the similarity of the Calder Hall station to conventional power stations becomes at this point more pronounced. The turbines and various other items of equip-

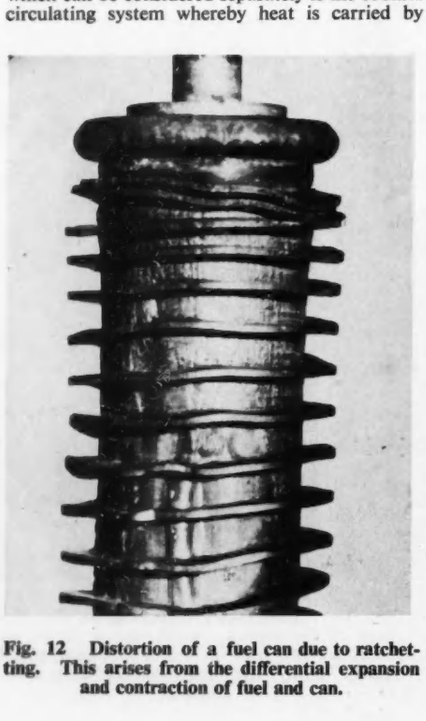


Fig. 12 Distortion of a fuel can due to ratchetting. This arises from the differential expansion and contraction of fuel and can.

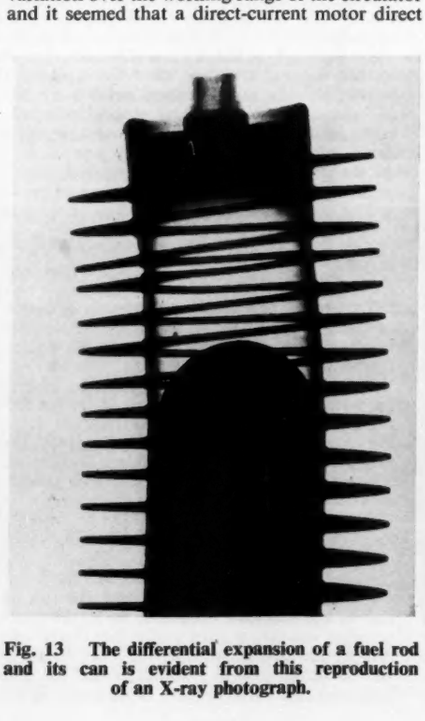


Fig. 13 The differential expansion of a fuel rod and its can is evident from this reproduction of an X-ray photograph.

Fig. 14 To attack the problem of ratchetting tests were carried out on cans without fins. Here is an example of severe distortion.

ment were made by C. A. Parsons and Company, Limited. Two turbo-alternators are associated with each reactor unit. Each turbine is of the reaction type and comprises a single-flow high-pressure turbine coupled in tandem with a double-flow low-pressure turbine. The provision of two exhausts enables a liberal exhaust area to be obtained, in conjunction with a relatively low blade speed. The blading material throughout is stainless iron and the rotor blades in the last two stages of the low-pressure turbine are fitted with erosion-resisting shielding.

The turbine blading and control valves are arranged to suit the characteristics of the reactor. When the set is operating at rated load there is a supply of steam from the boiler at a pressure of 200 lb. per sq. in. and temperature 310 deg. C. and a further supply at a pressure of about 53 lb. per sq. in. and temperature 171 deg. C. which enters the turbine after the fifteenth stage. These two supplies are taken to separate high-pressure and low-pressure steam chests, each of which contains an emergency stop valve and a governor valve. During starting, the high-pressure governor valve is speed controlled and surplus steam from the boiler is at this time discharged to a special dump condenser. As load on the turbine is built up a stage is reached when it will take all the high-pressure steam generated by the boiler, and pressure control then automatically comes into operation, controlling the high-pressure steam admitted to the turbine so as to keep the boiler pressure nearly constant. The position of the condensers in the feed water system is indicated in Fig. 8, while the dump condenser for No. 1 reactor appears in Fig. 9.

Charging and Discharging Fuel

Charge and discharge of the uranium fuel are effected from the roof of the reactor. For this purpose branches from the reactor pressure vessel extend from the top dome to the upper surface of the reactor top shield. One branch in the pressure vessel serves 16 uranium channels. In a typical operation an overhead crane lowers a charging chute into the pressure vessel branch which locates in the top surface of the graphite. Actuation of the chute enables each uranium channel to be connected in turn with the top of the shield. A charge machine comes into position over the top of the charging chute and supplies fuel elements from a magazine. Conversely, a discharge machine removes spent fuel elements by withdrawing them up the chute and placing them in a basket within the machine, where they are cooled. When full, the discharge machine is traversed to a position over a vertical shaft within the concrete shield. The basket is then released and lowered to the foot of the shaft into a shielded flask. The flask lid is automatically replaced and the flask withdrawn from the discharge room to be transported to the storage pond for irradiated fuel elements.

The adoption of the vertical channel system in the Calder Hall reactors presented the problem of charging and discharging fuel elements in a new form, as available experience was with reactors having horizontal channels. In these the canned fuel elements were inserted at one end and discharged at the other by simply pushing the string of elements. Charge and discharge, therefore, were both carried out in the same way. At Calder Hall, the channels, each of which holds a number of elements, are blind at the bottom, and so must be charged and discharged through the top end. From this it follows that spent elements in a channel must be removed before they can be replaced by new elements. The vertical arrangement also requires the elements to be lowered into place, quickly but gently, one at a time, and removed one at a time. Furthermore, as the whole reactor is surrounded by the pressure vessel, from which pressure tubes rise to the working floor Fig. 10, each tube must be provided with plugs and seals. These problems were tackled by Strachan and Henshaw Limited, who built the charge and discharge machines. There are two of each per reactor. These machines will be described in our next article on Calder Hall.

To charge elements into the reactor, the plant is first shut-down and de-pressurised; the cover plate on a charge tube is removed; and a temporary valve and gland assembly fitted in its place. The shield plug is withdrawn through the gland; a guide chute inserted in its place; and the temporary valve and gland removed. A valve on the chute prevents loss of coolant. A purged discharge machine is aligned over the guide chute and connected to it; the chute and machine valves are opened; and the grab is lowered for the first element. The element is engaged and hoisted into the magazine, the magazine moved one pitch, and the grab lowered for the next element and so on until the elements are cleared. When the magazine is full, the chute and machine valves are closed. The discharge machine moves away from the chute and its place is taken by a charge machine which fills the empty channels with new elements.

To enable charge and discharge machines to command, in rotation or in any desired order, all of the vertical channels a series of parallel steel rails is provided on the face of the charging floor, and these rail tracks are made available to any machine by provision of an electrically-driven cross traverser which serves all tracks. Except when being traversed, the machines move under their own power. When the magazine of a discharge machine is completely full of used elements, it travels to the traverser, and its place over the open channel is immediately taken by a charging machine. The traverser moves the discharge machine to a central point over a circular well, the top end of which is normally covered by a heavy slide door. A shield is removed from the bottom of the discharge machine; the slide door drawn aside; and the magazine is lowered by means of an electric hoist until it reaches the bottom of the well near ground level, where it is deposited in a heavy wheel-mounted cast-iron flask or immersed in a water tank. In this thick-walled container the elements are transported to the storage pond.

The whole area of the charging floor is commanded by an overhead travelling crane of 64 ft. span having twin hoisting motions, of 7·5 and 1 ton capacity. The duties of the crane are the handling of the charge plugs, guiding chutes, and local shield boxes, and maintenance of control rods and charging floor equipment generally. For many of these purposes it is necessary for all the motions of the crane to be smoothly variable from full speed down to a creep speed, and this is achieved by means of Ward Leonard control.

Graphite Moderator

The graphite core, into which the fuel elements are inserted, is 21 ft. high and 31 ft. in diameter, and is pierced by nearly 1,700 channels. It is composed of 58,000 graphite bricks and tiles machined to a tolerance of 0·002 in. This is necessary since small errors in single bricks taken cumulatively might yield major discrepancies over the entire core. The units are interlocked in such a way that, whatever dimensional changes of the structure might occur during the reactor's life, the spacing and size of the fuel and control-rod channels would not be affected. Another important factor was cleanliness, since any impurities might absorb the neutrons required for maintaining the chain reaction and converting uranium 238 into plutonium. In addition, foreign matter under irradiation might become radioactive and be carried into the coolant stream. The graphite was supplied by British Acheson Electrodes Limited, but the machining was carried out by the United Kingdom Atomic Energy Authority.

Fuel Elements

Like the graphite moderator, the fuel elements were entirely novel, and consequently little or no experience was available to assist in their design. They were therefore the subject of considerable research. Some of the investigations carried out were concerned with heat transfer, the compatibility of various canning materials with carbon dioxide at the temperatures involved, fabrication and production

Fig. 15 Heads of six control rods for the Calder Hall "A" station. There are 50 control rods per reactor, comprising hollow boron steel tubes enclosed in stainless-steel cylinders.

difficulties, the behaviour of particular fuel elements under the action of heat and radiation, and a variety of other metallurgical and related problems.

The material chosen for the fuel-rod cans was a magnesium alloy known as Magnox C, which unlike Magnox E another alloy considered, can be welded with relative ease. However, the can must be of extremely high purity since the slightest trace of other metals, lead for example, which might be introduced in working or hammering the alloy, lowers the melting point to such an extent that at operating temperatures contaminated parts of the can might liquefy. Iron, fortunately was found not to have this effect. The exclusion of undesirable materials from the fuel-can production plant was carried out to the extent of using other means than mercury-in-glass thermometers to measure the alloy temperature, since mercury is a particularly harmful contaminant. At present the finned cans are machined from solid, but more economic methods are under investigation.

In the reactor the fuel elements rest one on another in the vertical fuel channels and alignment is achieved by cone joints at each end. Care must be taken to avoid bowing of the lower elements, under the weight of those above, otherwise jamming might occur, and for this reason a shorter element was chosen than would have been preferred in terms of charging and discharging. Bowing also occurs under irradiation by a mechanism similar to that which causes the surface of the uranium rod to wrinkle. By use of fine-grained uranium this tendency can be minimised, and uranium rods are suitably refined by passing them through a high-frequency heating coil into a cooling spray.

Another problem arises from the differential expansion of the can and fuel rod and the need for tight contact between the two to give efficient heat transfer. The expansion coefficient of magnesium is roughly twice that of uranium, and on successive expansions and contractions the can tends to work up on the fuel rod with the result shown in Fig. 12. The extent of the difference in expansion may be gathered from the X-ray photograph reproduced in Fig. 13; while Fig. 14 shows severe distortion arising from this effect, which is known as "ratchetting." Means of limiting ratchetting have been developed at Harwell.

Control Rod Mechanism

The operational excess reactivity of the reactor is about 4 per cent. and this is controlled by 50 control rods, each 2 in. in diameter. These rods are uniformly spaced over the reactor core in an orientation parallel to the reactor channels. They are made of hollow boron steel tubes enclosed in stainless steel cylinders. The same rods are used for the shut-down function. The mechanisms are located in the top of the pressure

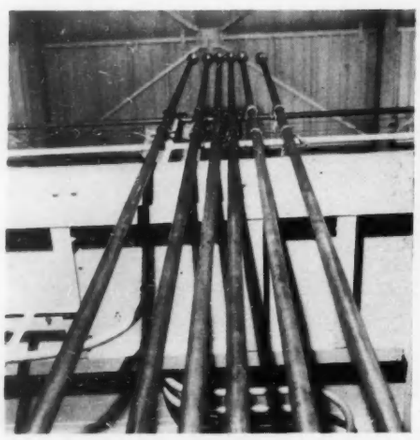


Fig. 16 The control rods are also used for shut-off purposes. Each rod is 30 ft. long and 2 in. in diameter, and weighs 120 lb.

vessel charge branches, and are situated entirely within the gas pressure circuit, so that seals and other sources of gas leakage and friction are eliminated. Thus only electrical connections pass through the pressure vessel wall. The system employed has been developed by the Metropolitan-Vickers Electrical Company, Limited. Fig. 15 shows the heads of six control rods; while the control rods themselves can be seen in Fig. 16.

The design was influenced by four main considerations: a high degree of operating reliability; failure to safety under all conditions; severe space limitation for the mechanism; and operation in an atmosphere of carbon dioxide at an elevated temperature, free from oxygen and water vapour and subject to some neutron bombardment. These conditions are conflicting and also give rise to serious lubrication problems. Thus the following units only were contained within the pressure circuit: a motor and electrically operated clutch, a controllable brake, a winding head and gearbox, and means of rod position indication. For the shut-off function the mechanism embodies an electromagnetic clutch to permit the rod to be dropped at will. Safety considerations require that, should the clutch fail to disengage, the rod must still fall, though at a lower rate. This precludes the use of a conventional high-speed motor with a large gear ratio, since on release the weight of the rod would not back-drive the system. A slow-speed high-torque motor must, therefore, be used and this called for special development to satisfy the conflicting requirements of high torque, low inertia and minimum size.

All working parts of the mechanism are in direct contact with the coolant gas at working pressure and temperature and are only accessible for maintenance at very infrequent intervals. Thus, reliable lubrication was a fundamental problem since conventional methods with oils, greases and graphite are ineffective in an atmosphere free from water vapour and oxygen. Metallic contact between working surfaces, even with light loadings and low speeds, can produce seizure under these conditions. Ordinarily, oxide films play an important part in the proper action of oil-type boundary lubricants, by preventing metallic surface contact. An extensive investigation and research programme was therefore carried out in connection with "dry film" lubricants. As a result of this, molybdenum disulphide coating was chosen for use on the working surfaces.

Under shut-off conditions the rod is released and falls under gravity with a controlled rate of fall. The final velocity is limited to a low value to bring the rod to rest without excessive shock. A permanent-magnet eddy-current brake was developed for this purpose in preference to the friction type, the performance of which would be uncertain in the coolant gas atmosphere. Permanent magnet rather than electrical excitation was adopted in view of the possible failure of supplies with consequent loss of braking action. During the initial fall of the rod, a high acceleration is desirable to obtain a rapid entry of the rod into the core and hence large neutron absorption. At the end of the travel a low speed is necessary to prevent damage to the rod and the stop. The first requirement calls for the minimum torque from the eddy-current brake at high speeds and the second for the maximum torque at low speeds. The above requirements are conflicting with the inherent characteristics of a permanent-magnet eddy-current brake. They were met by the use of an efficient and adjustable magnetic shunting system operated by the rod travel, which gave the correct torque-speed characteristic at every point during the fall of the rod. Development work was necessary in producing the adjustable magnetic shunting system to fit the physical space available. The forces involved in the movement of the shunt had to be kept small to ensure precise control. A disc-type rotor was adopted since this provided the minimum inertia for the torque required and hence maximum initial acceleration.

The rods are suspended by multi-strand flexible stainless-steel cable, edge wound on a narrow drum between side cheeks spaced one cable diameter apart. This arrangement provides the minimum bending stresses and avoids the risk of the cable turns becoming disarranged in the event of loss of tension. The motor is of the synchronous type with an unwound salient pole rotor which avoids the use of slip rings. The synchronous feature ensures that all the control rods maintain their pre-set relative positions from rest up to their maximum speed. A three-phase supply of variable frequency from zero up to the maximum designed figure, in either phase rotation, is necessary for the control of the motors. This is provided by a rotary frequency converter the speed of which can be changed relative to the synchronous speed by means of an interposed differential gear. Drive to the third member of the differential is through a speed selection gearbox of novel design which automatically provides a higher inward speed than outward, or reversal of direction in a positive and safe manner.

Indication of the rod position is obtained by means of a measuring wheel in contact with the cable. This drives a "magslip" data transmitter. The total angular rotation of the transmitter is restricted and ligament connections to the rotor used in place of slip rings. Type H insulation is used on all electrical windings on the motor, clutch coils and magslips. A more detailed description of the system will appear in our final article on Calder Hall.

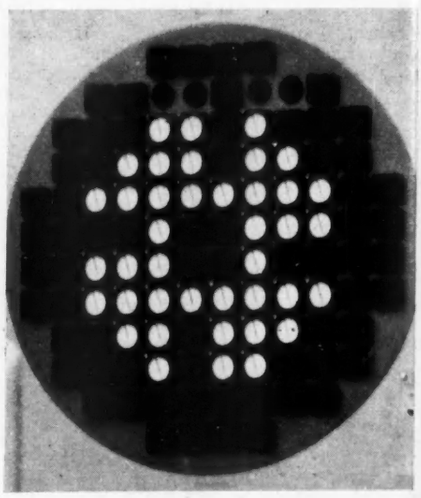


Fig. 17 Display panel representing plan of reactor. It is situated in No. 1 control room, where the bulk of the reactor's indicating, monitoring and control instrumentation is located.

General Data for Calder Hall "A" Station

PLANT

reactors	2
heat exchangers	8
main blowers	8
turbo-alternators	4
condensers	4
dump condensers	2
cooling towers	2

DATES AND PROGRESS

The above details are identical for Calder Hall "B."
Construction of Calder Hall "A" started in August, 1953.
Construction of Calder Hall "B" started towards the end of 1955 and should be completed during 1958.
Maximum labour force engaged in construction, 1,500.

FUEL ELEMENTS

Fissile Material	
Material	natural uranium
density	18·7 gm. per c.c. or 0·676 lb. per cub. in.
diameter of rod	1·15 in.
length of rod	40 in.
Cans	
material	magnesium alloy
inside diameter	1·165 in.
outside diameter	1·30 in.
diameter of fin tip	2·125 in.

GRAPHITE STRUCTURE

nominal core diameter	31 ft.
height of core	21 ft.
number of fuel channels	1,696

PRESSURE VESSEL

inside diameter	37·0 ft.
thickness of cylindrical shell	2·0 in.
thickness of domed ends	2·0 in.
maximum internal pressure	100 lb. per sq. in.
total internal volume	57,500 cub. ft.

COOLANT

material	carbon dioxide
temperature at pressure vessel inlet	140 deg. C.
temperature at pressure vessel outlet	336 deg. C.

SHIELDING

Biological Shield	
material	high-density concrete
side thickness	7 ft.
top thickness	8 ft.
Thermal Shield	
material	mild-steel plate
thickness	6 in.

HEAT EXCHANGERS

There are four heat exchangers per reactor, making a total of 8 for the Calder Hall "A" station, each generating high and low pressure steam. The details given below are for one heat exchanger and refer to the surface area for heat transfer exposed to live gas; the surface area in all cases is based on the outside diameter of the tubes.

high-pressure superheater	4,700 sq. ft.	64 elements in parallel (plain tubes)
high-pressure evaporator	31,500 sq. ft.	64 elements in parallel (studded tubes)
high-pressure high-temperature economiser	15,750 sq. ft.	42 elements in parallel (studded tubes)
low-pressure superheater	785 sq. ft.	32 elements in parallel (plain tubes)
low-pressure evaporator	31,500 sq. ft.	64 elements in parallel (studded tubes)
low-pressure and high-pressure economiser	15,750 sq. ft.	42 elements in parallel (studded tubes)
total	99,985 sq. ft.	

TURBO-ALTERNATORS

number of sets per reactor	2
maximum continuous rating	23,000 kW.
at a power factor of	0·8 lagging
speed	3,000 r.p.m.
generator voltage	11,500 (3 phase, 50 cycles per sec.)
high-pressure steam pressure at turbine stop valve	200 lb. per sq. in. abs.
high-pressure steam temperature at turbine stop valve	310 deg. C. (590 deg. F.
high-pressure steam per set (77 per cent. of total)	198,000 lb. per hr.
low-pressure steam pressure at turbine stop valve	53 lb. per sq. in. abs.
low-pressure steam temperature at turbine stop valve	171 deg. C. (340 deg. F.)
low-pressure steam per set (23 per cent. of total)	59,300 lb. per hr.
output	21,000 kW.
flow rate to condenser per set	257,300 lb. per hr.
abs. pressure at turbine exhaust flange	1·75 in. mercury
maximum cooling-water temperature	29·4 deg. C. (85 deg. F.)

COOLING SYSTEM

There are two cooling towers with split basins, and one pump house, serving the two reactors. The two towers feed into a common suction basin at the pump house with dam boards for partial shut down. Five pumps are available for delivering the water to the condensers of the two reactors.

half-basin capacity	687,500 gal.
cooling tower cooling range	30·5 to 21·1 deg. C. (87 to 70 deg. F.)
capacity per tower	3×10^6 gal per hr.
wet bulb temperature	8·3 deg. C. (47 deg. F.)
dry bulb temperature (humidity 60 per cent.)	11·1 deg. C. (52 deg. F.)
tower height above sill	290 ft.
tower diameter at ring beam	200 ft.
throat diameter	104 ft.

Faulty Fuel Element Detection

It is an important requirement for satisfactory operation of a nuclear power plant that apparatus is provided for the detection and localisation of fuel elements in the early stages of failure, such as a punctured can, in order to prevent the escape of fission products from the uranium to the primary coolant circuit. This problem has been well appreciated for some time by the Authority's reactor designers, and suitable equipment has been in continuous service in the Windscale production piles since their date of commissioning. The equipment for Calder Hall has been designed in the light of this operating experience; certain major changes in the equipment have been found necessary in order to satisfy the somewhat different requirements of this plant. Both the principle of the detector or "sniffer" plant and the related monitoring and control equipment will be described in our article devoted to contractors' contributions next week.

Fig. 17 shows one of many indicating devices in the reactor control room; it represents the general layout of groups of fuel channels seen in plan.

Sources

Apart from details supplied by the United Kingdom Atomic Energy Authority and various contractors, the information on which this article and that published on page 418 last week are based has been obtained from the following sources:

A Programme of Nuclear Power. H.M. Stationery Office. (Cmd. 9389).

Second Annual Report of U.K.A.E.A. April, 1955 to March, 1956.

Calder Hall, by K. Jay, Methuen and Co. Ltd., London, 1956.

"The Graphite-Moderated Gas-Cooled Pile and its Place in Power Production," by Sir Christopher Hinton (International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1955, paper 406).

"Mechanical Engineering Features of the Calder Hall Nuclear Power Station," by R. V. Moore and others. (Fifth World Power Conference, Vienna, 1956, paper 239 J/16).

"Investing in Atomic Energy," by F. M. Greenlees (Production Conference, London, 1956).

"The Calder Hall Nuclear Power Station," by K. J. Frost (paper presented to the Society of Engineers, October 1, 1956).

"The Role of the Engineer in the Design and Construction of Nuclear Power Plant," by W. R. Wootton, Babcock and Wilcox, Ltd., London, 1956.

ATOMIC REVIEW

Sharing Nuclear Power

The subject of "International Atomic Co-operation" has previously been treated in ENGINEERING *(May 25, page 397, 1956); this week we bring our report up to date—World atomic agency—Bilateral agreements—Collaboration—Euratom and O.E.E.C.—The next steps;—Notices—B.N.E.C. Calder Hall symposium—Film of Britain's atomic achievement;—Secret service.*

The atomic bomb may yet transform itself into political cement. There is certainly a tendency in this direction, evidenced by the moves and counter-moves of nations during the summer and autumn in efforts to find workable international agreements. These culminated in the conference called in Washington at the end of September, under the aegis of the United Nations, to consider a statute for a world agency drawn up in February by 12 nations which included the United States and the U.S.S.R. In the words of the president of the conference, Mr. J. C. Muniz, of Brazil, the draft statute is not "the perfect instrument it may become" but represents "a common denominator, a balance struck between reality and aspiration." The proposed International Atomic Energy Agency will have powers to channel nuclear materials from national stores into its own stores and thus begin "to diminish the potential destructive power of the world's atomic stockpiles."

This was the first of the two main objectives stated by President Eisenhower when he proposed the creation of the Agency in December, 1953. The second will be "to devise methods whereby fissionable material would be allocated to serve the peaceful pursuits of mankind." The draft statute provides for a staff of inspectors whose main task will be to ensure that the nuclear fuels provided by the Agency are not put to military uses. If world tension continues to fall it is not inconceivable that these powers would be extended to cover countries which produce their own needs of nuclear fuels. Meanwhile the powers proposed for the Agency are a means of safeguarding against the dangers inherent in supplying the small nations of the world with atomic power stations and fuels to burn in them. The alternative would be for the suppliers to carry out their own supervision, and this is a duty which few would care to have.

Bilateral Agreements

The advance towards an international atomic energy agency is a major step forward, but the path to complete agreement between the major producers of nuclear plant and equipment. The possession of atomic know-how remains, and is likely to remain for some time, a valuable political bargaining lever and an equally valuable commercial asset. That this is so is clear from the number of bilateral agreements concluded by the United S ates, U.S.S.R. and the United Kingdom in recent months. Soviet Russia's undertaking to supply Egypt with a 2,000 kW plant for a nuclear laboratory and a 3 million electron-volt nuclear reactor announced last July is a good example of the way in which political hooks can be baited. The erection of the plant under Russian supervision, the exchange of research workers, the training of Egyptian workers in Russian atomic establishments and other measures to establish close economic co-operation are the kind of steps which must lead to the economic dependence of the small country upon the large one.

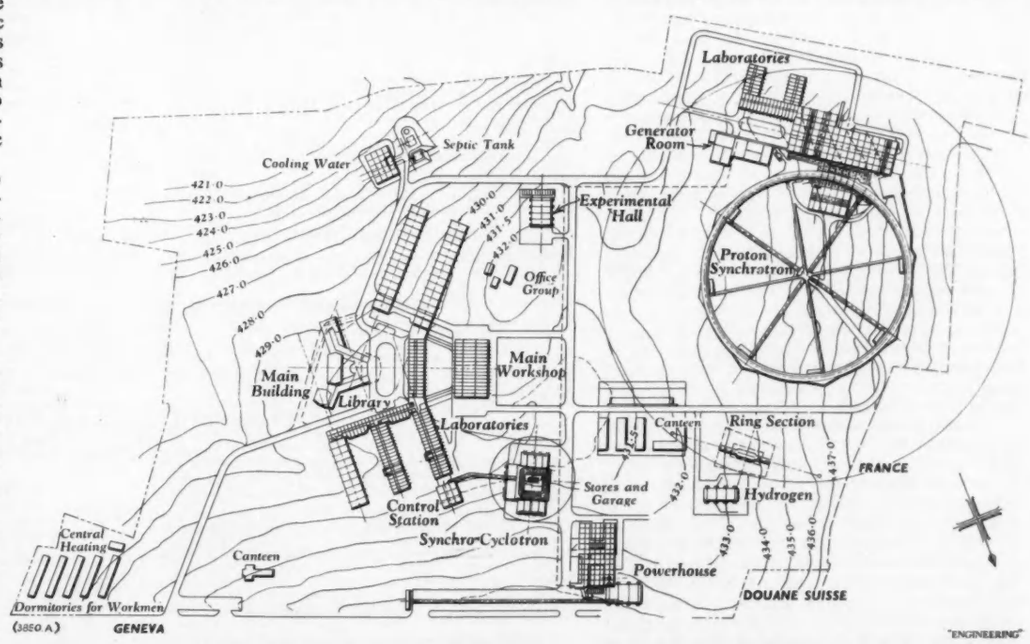
Pattern of International Co-operation

The pattern of international co-operation in the development of the peaceful uses of atomic energy which was outlined in an earlier article (ENGINEERING, vol. 181, page 397, 1956) remains confused, and is unlikely to become much tidier until the I.A.E.A. takes over its responsibilities and settles in its headquarters—likely to be in Vienna—in about a year's time. There has, however, been a move towards closer associations both in the political East and West. The Governments of the United Kingdom, the United States and Canada agreed last month on the interchange of "rights in inventions and discoveries in the atomic energy field, on which patents were held or applied for by one government in one or both of the other countries on November 15, 1955." This will have the effect of allowing the use in each country of inventions made during a period when atomic energy research and development was largely a Government monopoly in each of the three countries. Furthermore, each Government will have the right to grant licences to industry "in accordance with national policy." This is a major step forward in freeing private industry from restrictive patents—all of which arose out of war-time collaboration between the three governments—and is therefore of considerable importance to the growth of the atomic energy in each country.

Another important advance in the exchange of atomic information was made last June when the United Kingdom and the United States concluded an agreement to share know-how on military atomic energy engines—"packaged power reactors"—used to propel submarines and other naval vessels, aircraft and land vehicles.

This amends the 1955 British-American Treaty and makes provision for an exchange of information on the materials used in the atomic energy projects of the two countries as well as for an exchange of materials to avoid duplication of "highly expensive research work."

In the Soviet sphere of influence activity has hardly been less marked. A meeting of 50 atomic scientists from communist countries is being held this month in Dubna near Moscow to start a joint research project into "the industrial uses of nuclear energy." Comatom, the atomic energy agency of the Communist states will



International co-operation in nuclear research has already made a good start through the agency of CERN. The CERN site near Geneva will include a synchro-cyclotron and a proton synchrontron now under construction.

(See ENGINEERING, June 22, page 542, and August 10, page 189, 1956)

draw up the constitution of a joint Atomic Research Institute and set up a research establishment with plant, machinery and materials supplied by Soviet Russia.

Euratom and O.E.E.C.

The progress of Euratom, which is the nuclear agency proposed for the six Schuman Plan countries—Belgium, France, Western Germany, Italy, Luxembourg and the Netherlands—has been disappointingly slow. The conference held at Venice in May revealed differences in the views of France on the one hand, and Germany and the Benelux countries on the other. France, which holds the lead in atomic energy development in western Europe, wanted the Euratom agreement signed without delay but Western Germany would like to make the signature of the treaty conditional on the conclusion of a simultaneous agreement on a common market between the six countries. The French, who feel in a weak competitive position, do not want this and there is danger of a stalemate. The two major objections to Euratom raised by the Germans is that there will be discrimination between member states unless the French pledge themselves to renounce the use of atomic energy for war (Germany did so as a condition for being accepted into the North Atlantic Treaty Organisation).

Another is that the Germans object to the clause whereby member states are prevented from making direct purchases of nuclear materials from sources outside the organisation whenever Euratom supplies are not available in sufficient quantity or of the right quality. Another reason may well be that Germany has developed a new process for isotopic separation of uranium and the production of enriched fuel, which is said to be better and cheaper than any in use so far (possibly that described on page 92 of our issue of July 20). There is little doubt that German industry has high hopes of making up some if not all the lost ground in atomic energy research in a relatively short time, and that it does not wish to be harnessed to what could be a restrictive and slow moving organisation. The plans now in hand for the establishment of a nuclear research centre in North Rhine Westphalia—to include two nuclear reactors, an isotope separation plant, and six different institutes—certainly suggest that Germany will not be slow getting off the mark.

M. Jean Monnet called for urgent action on Euratom last month, emphasising the dependence of Western Europe on Middle East oil and her chronic shortage of solid fuels. His hope—that Euratom should start operations early next year—are not now likely to be realised. The insistence of all European countries concerned that Britain should come into the scheme in some way is, likewise, unlikely to succeed.

The British Government are much more likely to co-operate—in a limited way and with reservations—with the proposed European Nuclear Agency now being planned by a steering committee of the Organisation for European Economic Co-operation. At the July meeting of the ministerial council of O.E.E.C., Sir Edward Boyle, Economic Secretary to the Treasury, said that the British Government were willing to give technical assistance and perhaps take part in the exchange of material but explained that, after nine years' experience in the nuclear field, she could hardly be expected to co-operate to the full extent of her knowledge in a scheme in which most of the other members were starting from scratch. In this context, however, it would be wise to take note of the offer made by the Soviet foreign minister at that time to the western European countries. Mr. Shepilov proposed that they should pool their nuclear efforts with those of Comatom rather than set up their own organisation. A Soviet proposal was made for an all-European "Atoms for Peace" conference, with United States participation, together with a declaration that the Soviet Union "makes no secret of its nuclear achievements and willingly shares its experience with other countries."

Prospect

Thus many doors are wide open for co-operation between nations in the development of nuclear power. Politics and jockeying for favourable commercial positions are likely to continue to play their part. There has, however, been a considerable tightening in the co-operation of countries within each political bloc. The whole world is interested in obtaining the advantages of atomic energy, whether for generation of electricity or for other peaceful purposes. The fact that the Washington conference was held at all, and that 81 nations attended, suggests that the great powers are less intractable than they have been since the war. The fact that both the United States and the U.S.S.R. have criticised the Washington proposals for not going far enough and have re-asserted their desire for the prohibition of atomic and hydrogen weapons may yet lead to agreement and remove the threat of atomic war.

Notices

The programme for the British Nuclear Energy Conference symposium on "The Calder Works Nuclear Power Plant" (November 22 and 23), previously announced in ENGINEERING, in June (vol. 181, page 506, 1956), has recently been published. There will be five sessions and these are now to be held at Central Hall, Westminster. A film depicting the construction of the plant will be shown several times during the course of the symposium, at the Institution of Civil Engineers. The first session, dealing with the context, design and construction of the Calder Hall station, will include contributions by Sir Christopher Hinton, Mr. R. V. Moore and Mr. B. L. Goodlet. Mr. P. W. Mummery and Dr. A. B. McIntosh will be among the speakers in the second session on research problems; these cover metallurgy, fuel element heat transfer, shielding and experimental physics. Engineering design, light and electrical engineering, and the future development of the gas cooled reactor will be the subjects of the three sessions on the second day. The general chairman of the symposium will be Sir John Cockcroft. Inquiries regarding the symposium should be sent to the secretary of the B.N.E.C., 1 to 7, Great George-street, Westminster, S.W.1

A film entitled "Atomic Achievement" on Britain's civil atomic energy programme has just been completed by the Central Office of Information on behalf of the Foreign Office, and Commonwealth Relations and Colonial Offices. Copies are being sent to Embassies and High Commission Offices, so that showings can be arranged in overseas countries to coincide with the ceremony to be performed by Her Majesty The Queen on October 17, when Calder Hall is to be linked with the national grid. It is in Eastmancolor, lasts 20 minutes, and copies will be dubbed in 12 languages. It has been made by Rayant Films in co-operation with the United Kingdom Atomic Energy Authority.

Postscript

Next Wednesday Her Majesty The Queen is to perform the official opening of the Calder Hall nuclear power station (see page 469). It has been said that she will throw a switch and power will then flow into the national grid. This brings to mind a recent report concerning her famous predecessor Queen Victoria, who in 1897 opened Sheffield Town Hall. The new marvel electricity was to assist at the ceremony. A gold key was turned in a lock to which were connected two heavy cables, and the great town hall gates mysteriously swung open. In fact, it was revealed last week, electricity played only a minor part. Turning the key operated a buzzer whereupon two men hidden in the decorations hauled the gates open by ropes. The arrangements at Calder Hall are unlikely to be so Gilbertian.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

LONDON
London National Lecture. "Engineering Developments in Sound Broadcasting and Television," Presidential Address by Sir Harold Bishop. Institution of Electrical Engineers, Savoy-place, Victoria-embankment, W.C.2. Tues., Oct. 16, 6.30 p.m.*

NOTTINGHAM
"Rewinding a 10,000 kVA Turbo Rotor." Lecture and film, by A. D. Campbell. Nottingham Branch. East Midlands Electricity Board's Showroom Theatre, Smithy-row, Nottingham. Wed., Oct. 17, 7.30 p.m.

OXFORD
"Nuclear Reactors and Instrumentation," by D. D. Bowen. Oxford, Reading and Districts Branch. Collier Lecture Room, Regent's Park College, Pusey-street, Oxford. Sat. Oct. 20, 6.30 p.m.

SOUTHAMPTON
"Mineral Insulated Cables and Accessories," by R. B. Thom. Southampton Branch. Court Royal Hotel, Southampton. Mon., Oct. 15, 8 p.m.

TONBRIDGE.
"Electrical Safety," by S. J. Emerson. Kent Branch. Rose & Crown Hotel, Tonbridge. Thurs., Oct. 18, 8 p.m.

British Institute of Management

GLASGOW
"The Sales Manager and Production Management," by Peter Randolph. St. Enoch Hotel, Glasgow. Mon., Oct. 15, 7.15 p.m.

Building Centre

LONDON
Film Display. Wed., Oct. 17, 12.45 p.m.

Chemical Society

LONDON
Various original papers. Thurs., Oct. 18, 7.30 p.m.

ABERDEEN
"The Biochemical Revolution," by M. A. Pyke. Aberdeen Branch. Marischal College, Aberdeen. Fri., Oct. 19, 7.30 p.m.

DURHAM
"Isotopes in Industry," by Dr. H. Seligman. Newcastle and Durham Branch. Science Laboratories, The University, Durham. Tues., Oct. 16, 5.15 p.m.

EDINBURGH
"An Aspect of Natural Product Chemistry," by Professor F. S. Spring. Joint meeting with the Royal Institute of Chemistry and the Society of Chemical Industry. Edinburgh Branch. The Pharmaceutical Society, York-place, Edinburgh. Thurs., Oct. 18, 7.30 p.m.

HULL
"Separation of Volatile Substances by Gas-Liquid Chromatography," by Dr. A. T. James. Hull Branch. The University, Hull. Thurs., Oct. 18, 6 p.m.

Diesel Engineers and Users Association

LONDON
Annual General Meeting, followed by "Use of I.C. Engine Plant for Peak Loads on Electricity-Supply Systems," by J. P. R. Smith. Caxton Hall, London, S.W.1. Thurs., Oct. 18, 2 p.m.

Illuminating Engineering Society

GLOUCESTER
"Recent Developments in Plastic Materials," by P. H. Collins. Gloucester and Cheltenham Centre. Fleece Hotel, Westgate-street, Gloucester. Tues., Oct. 16, 6.30 p.m.

MANCHESTER
"School Lighting," Part I, by G. S. Pester and J. Blackie. Manchester Centre. Offices of the North Western Electricity Board, Town Hall, Manchester. Thurs., Oct. 18, 6 p.m.

Incorporated Plant Engineers

BIRMINGHAM
"Electrical Safety Concerning Building Sites and Civil-Engineering Projects," by G. L. Leighton. Birmingham Branch. Imperial Hotel, Birmingham. Fri., Oct. 19, 7.30 p.m.

BLACKBURN
"Steam for Process," by L. G. Northcroft. Blackburn Branch. Golden Lion Hotel, Blackburn. Thurs., Oct. 18, 7.30 p.m.

ROCHESTER
"Free-Piston Gas Generators," by P. Watson. Kent Branch. King's Head Hotel, High-street, Rochester. Wed., Oct. 17, 7 p.m.

Institute of British Foundrymen

IPSWICH
Presidential Address by H. A. Wincer. East Anglian Section. Public Library, Old Foundry-road, Ipswich. Tues, Oct. 16, 7.30 p.m.

Institute of Industrial Supervisors

LONDON
Discussion on "Paper Work and the Foreman." London South East Section. Woolwich Polytechnic, Calderwood-street, S.E.18. Thurs., Oct. 18, 7.30 p.m.

DEWSBURY
"The Supervisor and the Factories Act," by Miss A. Page. Bradford-Dewsbury Branch. Public Library, Wellington-street, Dewsbury. Wed., Oct. 17, 7.30 p.m.

LIVERPOOL
"Labour and Supervision in America," by Paul Miller. Merseyside Section. Stork Hotel, Liverpool. Wed., Oct. 17, 7.45 p.m.

Institute of Marine Engineers

LONDON
"The Junior Engineer's First Trip to Sea," by H. C. Gibson. Student Lecture. Mon., Oct. 15, 6.30 p.m.*

Institute of Road Transport Engineers

DURHAM
"Petroleum in Transport," by P. H. G. Crick. North Eastern Centre. Three Tuns Hotel, Durham City. Tues., Oct. 16, 7 p.m.

EDINBURGH
"Wear and Tear," by J. Johnson. Scottish Centre. North British Hotel, Edinburgh. Mon., Oct. 15, 7.30 p.m.

LEEDS
"Congestion of Traffic in Large Cities," by J. B. Buchanan. Yorkshire Centre. Great Northern Hotel, Wellington-street, Leeds, 1. Thurs., Oct. 18, 7.30 p.m.

PRESTON
"Design and Construction of a Modern Goods-Carrying Vehicle," by A. S. C. Marks. North Regional Centre. Victoria and Station Hotel, Preston. Tues., Oct. 16, 7.30 p.m.

Institution of British Agricultural Engineers

LONDON
John Fowler Memorial Lecture, by D. R. Bomford. Royal Society of Arts, 6 John Adam-street, W.C.2. Tues., Oct. 16, 4 p.m.

Institution of Chemical Engineers

LONDON
"Liquid-Liquid Extraction," by R. Gayler, H. R. C. Pratt, L. E. Smith and J. D. Thornton. Geological Society, Burlington House, Piccadilly, W.1. Tues., Oct. 16, 5.30 p.m.
CHESTER
"Fluidisation Applied to Handling of Bulk Solids," by D'Arcy Smith. North-Western Branch. Grosvenor Hotel, Chester. Tues., Oct. 23, 7 p.m.
LOUGHBOROUGH
"Manufacture and Industrial Uses of Hydrazine," by W. S. Stevens and J. West. Midlands Branch. College of Technology, Loughborough. Sat., Oct. 20, 3 p.m.
MANCHESTER
"Method of Design of Continuous Through-Circulated Dryers," by H. C. Glover and A. A. H. Moss. Tues., Oct. 16, 7 p.m.

Institution of Civil Engineers

LONDON
"Some Methods of Extending Life of Bridges by Repair and Strengthening," by J. D. West. Railway Division. Tues., Oct. 16, 5.30 p.m.*
"Control, Storage, and Use of Water," by G. M. Binnie. Second in series of six lectures on "The Conservation of Natural Resources." Thurs., Oct. 18, 5.30 p.m.*
"Skidding Resistance of Roads and Requirements of Modern Traffic," by C. G. Giles. Road Division. Tues., Oct. 23, 5.30 p.m.*

Institution of Electrical Engineers

LONDON
Chairman's Address on "The Electronic Age," by Dr. R. C. G. Williams. Radio and Telecommunication Section. Wed., Oct. 17, 5.30 p.m.*
Discussion on "Experiments for the Electronics Laboratory," to be opened by V. Attree. Fri., Oct. 19, 6 p.m.*
LEEDS
"Development of New 3 : 1 Pole-Changing Motor," by Prof. G. H. Rawcliffe and B. V. Jayawant. North Midland Centre. Central Electricity Authority, Yorkshire Division, 1 Whitehall-road, Leeds. Tues., Oct. 16, 6.30 p.m.
LIVERPOOL
"Germanium and Silicon Power Rectifiers," by T. H. Kinman, G. A. Carrick, R. G. Hibberd, and A. J. Blundell. Mersey and North Wales Centre. Liverpool Royal Institution, Colquitt-street, Liverpool. Mon., Oct. 15, 6.30 p.m.
MANCHESTER
"Physical Properties and Impulse Strength of Paper," by H. C. Hall and E. Kelk; "Impulse Strength of Lapped Impregnated Paper Dielectric," by H. C. Hall and D. J. Skipper; and "Breakdown under Impulse Voltages of Solid and Liquid Dielectrics in Combination," by W. G. Standring and R. C. Hughes. North-Western Centre, Supply Group Meeting. Engineers' Club, 17 Albert-square, Manchester. Tues., Oct. 16, 6.15 p.m.
SOUTHAMPTON
"Potentialities of Railway Electrification at Standard Frequency," by E. L. E. Wheatcroft and H. H. C. Barton. Southern Centre. The University, Southampton. Wed., Oct. 17, 6.30 p.m.

Institution of Engineers and Shipbuilders in Scotland

GLASGOW
"Some Aspects of Ship and Propeller Experiments," by Prof. A. M. Robb. Tues., Oct. 23, 6.30 p.m.

Institution of Heating and Ventilating Engineers

SHEFFIELD
"Process Steam," by L. G. Northcroft. Yorkshire Branch. Royal Victoria Station Hotel, Sheffield. Wed., Oct. 17, 7.30 p.m.

Institution of Mechanical Engineers

LONDON
Presidential Address on "Motive Power on Sea and Land," by T. A. Crowe. Fri., Oct. 19, 6 p.m.*
BIRMINGHAM
Paper by B. E. Eltham. Midland Graduates' Section. James Watt Memorial Institute, Great Charles-street, Birmingham. Mon., Oct. 15, 6.30 p.m.*
BRISTOL
"Wider Aspects of Management," by Sir Ewart Smith. Western Branch. Large Lecture Theatre, Engineering Laboratories, University Walk, Bristol, Tues., Oct. 16, 7 p.m.*
GLASGOW
Paper by Ronald Flockhart. Scottish Graduates' Section. Royal Technical College, Glasgow. Mon., Oct. 15, 7.30 p.m.
HULL
"Design and Construction of Aden Oil Harbour," by J. E. G. Palmer. Joint meeting between the Yorkshire Branch and the Hull Association of Engineers. Royal Station Hotel, Hull. Wed., Oct. 17, 7.30 p.m.
LEEDS
Paper by C. Ellam. Yorkshire Graduates' Section. Chemistry Lecture Theatre, University Leeds. Thurs., Oct. 18, 6.30 p.m.
PETERBOROUGH
"Fuel Requirements of the Small Automotive High-speed Diesel Engine," by G. M. Barrett. East Midlands Branch. Conference Room, Central Electricity Authority Generating Station, Peterborough. Wed., Oct. 17, 7.45 p.m.

Institution of Mining and Metallurgy

LONDON
"Changes in Copper Solubility During Flotation of Malachite," by E. J. Pryor and G. M. Lowe, and "Solvent Extraction Process for Purification of Niobium from Ores or Ferroniobium," by Dr. J. M. Fletcher, Dr. D. F. C. Morris and A. G. Wain. Geological Society, Burlington House, Piccadilly, W.1. Thurs., Oct. 18, 5 p.m.*

Institution of Production Engineers

LONDON
"Impact of Production Engineer on Work and Payment Structure of Industry," by Dr. E. Jacques. South Eastern Region. Royal Empire Society, Craven Street, W.C.2. Thurs., Oct. 18, 7 p.m.
BIRMINGHAM
"Safety as seen by Production Engineer and Factory Inspector," by J. Silver and A. Hillier. Midlands Region. James Watt Memorial Institute, Great Charles-street, Birmingham. Wed., Oct. 17, 7 p.m.
COLCHESTER
"Jobbing Foundry Work To-day," by A. Talbot. Eastern Region. Britannia Works Canteen, Davey, Paxman & Co. Ltd., Colchester. Fri., Oct. 19, 7.30 p.m.
COVENTRY
"Component Production from Metal Powder," by G. R. Bell. Midlands Region. Craven Arms, High-street, Coventry. Mon., Oct. 15, 7 p.m.
DERBY
"New Techniques in Non-Destructive Testing," by W. G. Cooke. North Midlands Region. Derby College of Arts, Green-lane, Derby. Mon., Oct. 15, 7 p.m.
MIDDLESBROUGH
"Glass Fibre and its Use in Reinforced Plastics," by A. R. Henning. Northern Region. Cleveland Scientific and Technical Institution, Corporation-road, Middlesbrough. Mon., Oct. 15, 7 p.m.
NEWCASTLE-UPON-TYNE
"Materials Handling for Batch Production," by A. Harvey. Northern Region. Neville Hall, Newcastle. Mon., Oct. 15, 7 p.m.
NORWICH
"What is Efficiency ?" by A. G. Northcott, Eastern Region. Assembly House, Theatre-street, Norwich. Wed., Oct. 17, 7.30 p.m.
PETERBOROUGH
"Design for Production," by F. E. Butcher. North Midlands Region. White Lion Hotel, Church-street, Peterborough. Tues., Oct. 16, 7.30 p.m.
SOUTHAMPTON
"Plastics—Materials, Processes, Machines," by D. C. Nicholas. Southern Region. Polygon Hotel, Southampton. Thurs., Oct. 18, 7.15 p.m.
WOLVERHAMPTON
"Electronic Control in Industry," by E. Heys. Midlands Region. Wolverhampton and Staffs. Tech. College, Wolverhampton. Wed., Oct. 17, 7.30 p.m.

Institution of Structural Engineers

CARDIFF
Chairman's Address on "Modern Steelwork Fabrication," by G. E. Cooper. Wales and Monmouthshire Branch. South Wales Institute of Engineers, Park-place, Cardiff. Tues., Oct. 23, 6.30 p.m.
LEEDS
Chairman's Address, by A. L. Percy. Yorkshire Branch. Central Electricity Authority Offices, Whitehall-road, Leeds. Wed., Oct. 17, 6.30 p.m.
MANCHESTER
Chairman's Address, by J. B. G. Martin. Lancashire and Cheshire Branch. College of Technology, Manchester. Thurs., Oct. 18, 7.15 p.m.
MIDDLESBROUGH
Chairman's Address, by T. Johnson. Film, "Oil Harbour at Aden." Northern Counties Branch. Cleveland Scientific and Technical Institution, Corporation road, Middlesbrough. Tues., Oct. 16, 6.30 p.m.*

Junior Institution of Engineers

LONDON
"Oil Additives," by S. E. Holmes. Fri., Oct. 19, 7 p.m.*

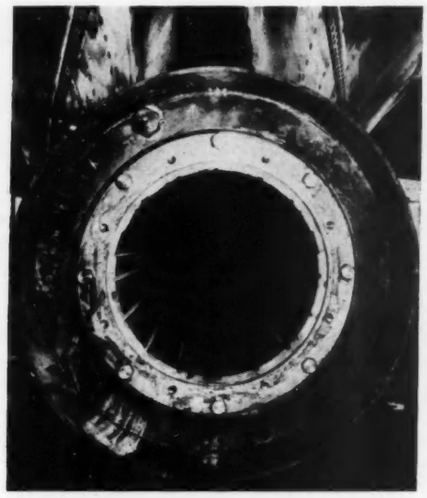
Royal Aeronautical Society

LONDON
"Importance of Time in Aircraft Manufacture," by Air Comdre. F. R. Banks. Institution of Mechanical Engineers, 1, Birdcage-walk, S.W.1. Wed., Oct. 17, 6 p.m.*

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

* An asterisk is placed where it is understood that tea is available prior to the time stated.

Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 5927.)
British Institute of Management, Management House, 8 Hill-street, London, W.1. (GROsvenor 6000.)
Building Centre, 26 Store-street, London, W.C.1. (MUSeum 5400.)
Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Diesel Engineers and Users Association, 19 Old Queen-street, London, S.W.1. (TRAfalgar 5597.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester 3. (Blackfriars 6178.)
Institute of Industrial Supervisors, 24 Albert-street, Birmingham 4. (Midland 6971.)
Institute of Marine Engineers, 85 The Minories, London, E.C.3. (ROYal 8493.)
Institute of Road Transport Engineers, 69 Victoria-street, London, S.W.1. (ABBey 6248.)
Institution of British Agricultural Engineers, 6 Buckingham-gate, London, S.W.1. (TATe Gallery 8589.)
Institution of Chemical Engineers, 56 Victoria-street, London, S.W.1.(VICtoria 6161.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. (Central 5181.)
Institution of Heating and Ventilating Engineers, 49 Cadogan-square, London, S.W.1. (SLOane 3158.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Mining and Metallurgy, 44 Portland-place, London, W.1. (LANgham 3802.)
Institution of Production Engineers, 10 Chesterfield-street, London, W.1. (GROsvenor 5254.)
Institution of Structural Engineers, 11 Upper Belgrave-street London, S.W.1. (SLOane 7128.)
Junior Institution of Engineers, Pepys House, 14 Rochester-row, London, S.W.1. (VICtoria 0786.)
Royal Aeronautical Society, 4 Hamilton-place, London, W.1. (GROsvenor 3515.)



The illustration shows a stern-tube bearing in Tufnol fitted in the shaft housing of a cargo boat.

TUFNOL STERN-TUBE BEARINGS

Of more than 100 ocean-going ships that have been fitted with rudder bearings of Tufnol since 1949, none has yet had to have the bearings replaced due to normal wear. This success led to the introduction of the material for stern-tube bearings in 1952, and for the last four years the large ships that have been so fitted have all reported complete success. In one ship the wear amounted to only 0·045 in. in two years. During its previous 20 years of service this ship had to be "rewooded" every year.

One of the latest vessels in which Tufnol has been used is the m.v. André Masset, a 5,600 ton bulk carrier recently built by Wm. Pickersgill and Sons for Union Industrielle et Maritime, Paris, with a N.E.M.-Doxford 2,600 b.h.p. engine as fitted by the North Eastern Marine Engineering Company Limited. Not only is she fitted with Tufnol rudder and stern tube bearings, but her generator mountings are of the same material.

Apart from long life, the principal assets of Tufnol as a bearing material are strength, resistance to corrosion and a very low water absorption. In addition, the bearings will not crack or warp and they can be stored dry for long periods without the need for special precautions. Tufnol is manufactured by Tufnol Limited, Perry Barr, Birmingham, 22B.

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HYDRO-ELECTRIC POWER IN GREAT BRITAIN

The history of hydro-electric power in Great Britain, and the changes that have been brought about in civil-engineering design and practice by the construction of the resulting projects, was discussed by Mr. J. Guthrie Brown in his presidential address to the Institution of Structural Engineers on Thursday, October 4. Dealing with his subject in strict chronological order, brief descriptions were given of the projects from the earliest—Foyers, the British Aluminium Company's scheme on Loch Ness and completed in 1896—until the most recent—Breadlebane and Lednock, where fly-ash cements have been used.

In tracing the changes that the last 60 years have brought to design, the new President contrasted the earth and masonry dams of the early 1900's with the arch dams of the 20's and with the prestressed gravity dam at Allt-na-Lairige. The reduction in labour force made possible by the more extensive use of plant and machinery, particularly for concrete mixing and placing and for tunnelling were reviewed in the address, which will be published, *in extenso* and illustrated, in the *Structural Engineer*.

TOWARDS SPACE FLIGHT

THE INTERNATIONAL ASTRONAUTICAL CONGRESS

For the first time in the history of the International Astronautical Federation, which has recently been holding the seventh International Astronautical Congress in Rome, professional astronautical engineers and scientists attended the Congress and delivered papers.

THE VANGUARD SATELLITE

Several of the papers on artificial satellites were a direct result of the American Vanguard satellite project, described in some detail in the paper by Mr. N. E. Felt, entitled " The Vanguard Satellite Launching Vehicle." The Vanguard is a three-stage vehicle without fins, and will be the largest rocket ever to be flown without these stabilising components. Guidance and stability will be attained through the use of a gimballed rocket motor. The three stages partially fit inside one another, and the whole vehicle has a length of 72 ft. This compares with the Viking of 45 ft. The maximum diameter is the same as that of the Viking, namely 45 in., and the take-off gross weight is 22,600 lb. (Viking 15,000 lb.). The first stage, being built by the Glenn L. Martin Company, is powered by a rocket motor using liquid oxygen and petrol as propellants. The second stage also uses a liquid-propellant rocket motor, but in this case the propellants are white fuming nitric acid and unsymmetrical dimethyl-hydrazine. This motor is also gimballed and the guidance equipment for both stages one and two is contained in stage 2.

The motor for stage 1 uses a turbo-pump for injecting the propellants into the combustion chamber, whereas the stage 2 motor uses pressurised tanks. The third stage is a solid-propellant rocket and contains the 20 in. spherical satellite in the nose, where it is covered with a cone to protect it from aerodynamic heating. The first stage will lift the entire vehicle to 36 miles altitude, when the propellants will be exhausted and the second stage fired. The second stage will take the remainder of the vehicle to 140 miles altitude, and both the second and third stages will then coast to a height of about 300 miles. During this time, the altitude will be controlled by means of small tangential jets of residual pressurising gas from the second stage. This type of control was successfully developed for the Viking rocket. The third stage will be spun and then released and fired, the solid propellant rocket bringing it up to a final velocity of approximately 26,000 ft. per second. The satellite will then be separated from the third stage rocket; the third stage itself will also become a satellite, since its velocity will be identical to that of its pay-load. A certain amount of difficulty is expected in placing the satellite in its required orbit. Fairly wide tolerances are being allowed and the apogee is to be no greater than 1,400 miles and the perigee no less than 200 miles. This allows an altitude error of $\pm 2\frac{1}{2}$ deg. and a velocity error of $\pm$ 340 m.p.h.

SKIN HEATING OF SATELLITES

One of the many problems to be investigated by the Vanguard artificial satellites is that of aerodynamic heating at extreme altitudes. Mr. T. R. F. Nonweiler, of the College of Aeronautics, Cranfield, discussed this problem in his paper " Skin Heating During Re-entry of Satellite Vehicles to the Atmopshere." He confined his paper to discussing the limit to the maximum temperature reached close to the wing leading edge in sustained level flight at orbital speeds, as imposed by the action of conduction of heat within and along the skin. He considered that there might well be other, and perhaps lower, limits, but this one could be established with a fair amount of certainty. The results deduced are relevant only to a wing of wedge section utilising a thin skin, since the boundary-layer flow about such a section can most easily be deduced for flight at extreme speeds. The temperature reached by the fuselage of a returning vehicle will also present a problem of some importance but, since the wing loading must be low, the wing thickness can be quite large without introducing a weight penalty and consequently it seems likely that such a vehicle will be an all-wing design. Mr. Nonweiler showed that particular attention to the flight plan and overall design can greatly simplify the problems of kinetic heating. Nose temperatures need not be greater than 1,000 deg. C. The greater the skin thickness, the lower would be the maximum temperature, but in practice there would always be a limit to the allowable thickness. Again, the emissivity of the outer surfaces should be made as high as possible.

OBSERVING THE ARTIFICIAL SATELLITES

The paper by Mr. F. L. Whipple, on " The Visual Programme for the Artificial Satellite Programme of the International Geophysical Year," included a discussion of proposed amateur activities. The optical tracking programme consists of: (1) the use of twelve 20 in. Schmidt photographic cameras, (2) the visual observation programme involving volunteer observers around the world using simple optical aids for the early acquisition and the tracking of the later stages of the satellite's life, and (3) the professional astronomers' programme using specialised equipment already available in the astronomical observatories of the world. The amateur programme is called Project " Moonwatch " to distinguish it from the precision photographic tracking, and the Smithsonian Astro-physical Observatory is issuing a regular publication— " Bulletin for Visual Observers of Satellites."

Before the Schmidt cameras can effectively go into action, it is essential to produce preliminary data on the satellite's orbit. This will be done by means of the Minitrack radio equipment to be carried by each satellite and by the various groups of amateur observers. These latter will become essential to the programme if, for any reason, the Minitrack equipment fails to operate. The programme depends on the use of optical " fences " to prevent any possibility of a satellite slipping through successive zones of observation without being seen. Each group will comprise up to thirty observers using wide aperture instruments which will be supported on mountings in such a way that the fields overlap along the meridian " fences." The group will be alerted at the appropriate time and will observe throughout the period during which the satellite will be passing overhead. On sighting the satellite, several instruments will be used to follow its path across the sky and the exact times at which it passes various stars will be determined by means of accurate time signals derived through short-wave radio. The data will immediately be passed back to the central computing machine which will straightway incorporate it into an improved solution for the motion of the satellite.

MOON SATELLITES

One of the next steps after the Vanguard programme will probably be the setting-up of artificial satellites of the moon. Some of the problems involved were discussed by Mr. R. W. Buchheim, of the Rand Corporation, in " Artificial Satellites of the Moon." For a stable retrograde orbit, that is, one revolving in an opposite direction to that of the earth/moon system, an initial accuracy of attitude and velocity 20 times greater than that required by the Vanguard would be needed. For a direct orbit, that is, one in the same direction of rotation as the earth/moon system, this accuracy would again need to be doubled. The effective life of such a satellite with a radio transmitter would be severely limited by the power-supply capacity, assuming batteries to be used. It would be highly desirable to make the satellite optically observable, thus giving it effectively an infinite life. Mr. Buchheim showed that satellites of visual magnitudes 10 to 6 would be 132 to 832 ft. in diameter and, assuming the skin to be made of aluminium foil 0·0001 in. thick, the weights would be 79 lb. to 3,140 lb. A rocket vehicle with an overall weight of about 1,000,000 lb. could project a 500 lb. pay-load from the earth on to a trajectory of the type required. About half of this pay-load would have to be devoted to decelerating the rocket at the moon. If half of the remaining 250 lb. of the pay-load could be devoted to the satellite's skin, a satellite of 166 ft. diameter could be erected. This, when in full phase, would have a visual magnitude of 9·5 and could be reliably observed when at one diameter from the moon's bright limb.

SOLAR POWER

Propulsion is the most difficult problem in any proposed space flight project. In addition to the conventional chemical rocket, various other types of propulsion in space have been proposed. The best known of these is the " working fluid " atomic rocket which utilises a low molecular-weight fluid such as hydrogen or helium, heated to a moderately high temperature by a nuclear reactor and expanded through a conventional nozzle. The nuclear reactor can also be used to produce electricity which can be then applied in any one of several ways. Two methods which have received a great deal of attention during recent years are the ion rocket, in which the electricity is used to produce a stream of ions, and the arc-heating system, in which a working fluid is raised to a very high temperature in an electric arc and then expanded.

Solar energy will almost certainly be used to produce small quantities of electricity in space for auxiliary purposes. Its use for main propulsion purposes has also been suggested several times and Mr. K. A. Ehricke, in his paper " On the Application of Solar Power in Space Flight," analysed the problem in some detail. His proposal is to collect solar energy from a large area by means of pressure-stabilised spherical collectors, one half of each being sprayed with silver or aluminium. Such spheres could be stabilised at a very low pressure, thus permitting a collector of extremely low weight. The solar energy would be concentrated on to pipes containing a working fluid which would then be passed to an exhaust nozzle and expanded in the conventional manner. The resulting large dimensions of such a solar-powered vehicle would require very long pipe-lines from the tank to heater and back to the exhaust nozzle. Elaborate insulation of these lines could not be tolerated for weight reasons and regenerative cooling would not be feasible in view of the pipe-line lengths. As a consequence, the temperature of the working fluid would have to be limited to about 1,000 deg. K. No spectacular increase in specific impulse over that obtainable from normal chemical propellants could be expected, but by using hydrogen a practical figure of about 450 seconds should be possible.

Such a system could, in practice, be used to produce only very low thrusts and could, therefore, only be applied in outer space. Flight under low-thrust conditions involves longer burning times than is the case with chemical rockets. Burning times would be measured in hours or days, and the propellant would thus be lifted to considerably greater altitudes before it was consumed. This involves a penalty in the form of " gravitational loss," and the author showed that the use of a solar propulsion system for a circum-lunar trip would be impractical. At greater distances from the earth, gradual acceleration along a low-thrust orbit carries less penalty in terms of gravitational loss. The use of a solar propulsion system for the circum-navigation of Venus, or perhaps even a flight to Mars, would necessitate considerably lower-weight vehicles than would conventional chemically-propelled rockets. The complete Proceedings of the Congress are to be published by the Associazione Italiana Razzi, Piazza S. Bernado 10, Rome, Italy.

At the works of Foundry Services, Limited, the powdered materials, proportioned by weight on an upper floor, pass by gravity to a line of mixers. From here they can be fed into containers, or taken to pelleting machines, where the pellets are packed in cartons and stacked on pallets ready for removal by fork-lift truck to the warehouse.

CHEMICAL AND METALLURGICAL PRODUCTS FOR FOUNDRIES

MANUFACTURE AND PACKING

Foundry Services, Limited, Long Acre, Nechells, Birmingham, 7, are well known for their large range of chemical and metallurgical products for use in foundries. The products, which can be divided roughly into four main groups—fluxes, feeding compounds, dressings, and auxiliary products—total over 200. They are sold in moulded shapes, as pellets or briquettes, or packaged in paper or other containers in pre-weighed quantities. This method of marketing is of particular value in foundries, as it is only necessary to instruct unskilled labour to use a specified number of packages of material for a particular operation; there is no need to provide accurate weighing apparatus or labour sufficiently skilled to use it. In conjuction w.th its production of the various compounds, the company maintains an advisory service which investigates customers' problems, including the question of faulty castings, and means for preventing them. This service is used extensively; 2,500 samples of castings were examined, and advice was given on their production during last year. Foundry Services, Limited, have thus to maintain a factory for the production of their compounds, and large chemical and metallurgical laboratories, together with an experimental foundry where products and techniques can be tested.

Until recently both activities were concentrated at Long Acre, Birmingham, where the company's head office is situated. In addition, a small amount of production was carried on at Drayton Manor, Tamworth, Staffordshire, in a factory originally erected by the Ministry of Supply during the war. New premises and equipment at Tamworth have now been brought into commission, and all the manufacturing is carried on there. The Tamworth premises cover a total of 134,000 sq. ft. on a site of approximately 40 acres. Nechells now houses only the offices and laboratories. Facilities are available there for investigating current problems as submitted by customers, and also for long and short-term development and research work.

A very important product of the company is the series of exothermic compounds which are sold under the trade name of " Feedex," and a separate department is devoted to the manufacture of these compounds at Tamworth. " Feedex " is a mouldable feeding and pipe-eliminating compound made of strongly heat-producing materials. A major constituent of the compound is aluminium, and the raw material used at Tamworth is actually a trade waste product. It is purchased in the form of grinding sludge from machine shops, and is de-greased in a vacuum plant of special design. Adjoining the de-greasing plant is the mixing equipment for " Feedex "; this consists of two drum-type mixers each of 4,000 lb. capacity. Because of the possibility of explosion of the finely divided aluminium powder, the mixers are installed in blast-proof chambers, the doors of which are electrically interlocked with the mixer controls and charging apparatus. Mixer charges, consisting of aluminium powder and other ingredients in powder form, varied according to the conditions under which the compound will be used, are made up at ground floor level and raised in hoppers by electric hoist to charging chutes, which are fitted with vibrators to assist the discharge of the powder. In this department all the tools are of brass, to obviate the possibility of the production of sparks.

From the " Feedex " plant the compound, in powder form, passes to the main production building, where it joins the incoming stocks of chemicals. Extensive storage facilities are provided at this end of the building so that large stocks of purchased chemicals can be maintained. From this point materials flow through the production machinery to the finished products stores and dispatch department at the opposite end of the building.

The majority of the company's compounds are, like " Feedex," originally in powder form, and the plant at Tamworth includes an extensive range of mixers. External heaters have been provided to ensure that the products are free from moisture. The mixers are on the ground floor, and charging is done from an upper floor by gravity. On this floor the charges are made up, and since many finely-divided powders are involved, there is a particularly effective dust-extraction system. After mixing, the compounds are dealt with in one of three ways: " Feedex " is moulded into sleeves and other shapes as required, and baked in gas-fired core stoves, other powders are either pelleted or made into bricks, or else they are packeted in large or small quantities as required.

" Feedex," being used for providing heat in the feeding heads of moulds for castings or ingots, is usually supplied in the form of sleeves, which are made of a size and shape to suit a particular customer's requirements. Some " Feedex " is moulded into other shapes, and a certain amount is dispatched in powder form for the customer to mould his own shapes or sleeves as required. Because of its wide application, the sizes and shapes of sleeves made from " Feedex " are very numerous, and the quantities required vary greatly. Several methods are employed in the production of sleeves. For small runs hand methods are used, and benches are provided on which sleeves are made in a manner similar to that used for cores. Longer runs are made in multiple moulds on jolt-ram machines, and for high-speed production of suitable sizes and shapes there is a " Hansberg" core shooter. Stoving follows the moulding of " Feedex " sleeves, which are then ready for packing and dispatch.

Numerous other powdered materials are dealt with, many of them being mixed with binders and compressed into briquette or tablet form. For handling these products, there are several types of machine, ranging from specially-adapted brick presses to Manesty pelleting machines. There are also in this section of the factory some " Bipel " tableting machines of new design made by B.I.P. Engineering Limited, Streetly, Staffordshire. For filling paper packets and other containers with the powders, there are automatic weighing and packeting machines.

One of the products made at Tamworth is a deoxidiser for copper, nickel, and their alloys, which is used by being plunged deeply into the molten metal. To enable this to be done the finely granular material is packed, in predetermined quantities, in pure-copper tubes, which melt and liberate the compound below the surface of the metal. A section of the main production shop at Tamworth is devoted to the manufacture and filling of these deoxidising tubes. Copper strip is first cut to length automatically, a strip of coloured plastic being rolled on to the copper just before cutting takes place, in order to identify the contents when the packaging is completed. The cut strips are then formed in hand presses and placed in the feed conveyor of an automatic filling machine which also closes the end of the tube. This is then ready for packing and dispatch.

All finished products pass to the extensive warehouse at the end of the production section, and large stocks are kept there. As the products vary in bulk, and the quantities being dispatched vary from small amounts which can be sent by parcel post to whole lorry loads, the design of the warehouse has been based on the use of fork-lift trucks. Products are picked up by the trucks at the point where they are packed, transported to the warehouse and stacked there as required. The clear floor space, and the availability of the whole building up to roof level give great flexibility. A separate department deals with packing for export, about 25 per cent. of the output at Tamworth being sent overseas.

THE HUMAN ELEMENT

Coloured competition in the Labour market—Organisation and consultation the key to industrial progress—Fishing for an issue—Automation may bring some redundancy but firms will be prepared—German unions welcome automation, given certain safeguards—Vacancies in Civil Service remain unfilled.

★ ★ ★

Colour Bar at Blackpool

No subject is more dangerous for a political party which claims to represent the working man than the colour bar. It is a matter which probably calls for a doctrinaire approach in the first instance, just as the slave trade did, but it is full of pitfalls for those who begin to put principles into practice. Being a question of principle it is eminently suitable for an uncompromising attitude by honest Socialists. It is, however, the rock on which founders any idea that the Labour Party is a Socialist organisation pure and simple, and at the same time a class party to save the working man from the " bosses."

The trap was obviously not on view at Blackpool last week at the annual conference of the Labour Party, when resolutions on plural societies calling for an attack on the colour bar in varying degrees of ferocity were discussed. It was quite overlooked that the basis of the colour bar is prejudice and ignorance and that it always flares up quickest and in its least pleasant form among those most likely to suffer from coloured competition in the labour market, namely the unskilled white worker. The fact that a few educated people whose skins are not white by western standards are excluded from a few hotels is regrettable. As a problem it is nothing compared with what would happen, even in this country, if the many coloured workers in industry were not dismissed at the first sign of a shortage of jobs. This is a subject for education and slow progress-not hurried enthusiasm which can get close to hypocrisy.

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Four Issues for the Future

An excellent paper given recently by Mr. Paul Hanika, of the Royal College of Science and Technology, Glasgow, to the Institution of Engineers and Shipbuilders in Scotland, on the elements of industrial organisation, and their significance, underlines four issues for the future.

In Mr. Hanika's view, these are as follows. First, there is the problem of getting the benefit of specialised management techniques—involving greater and greater numbers of people—while minimising the drag on effort arising from co-operation between such numbers. On this he is fairly optimistic because he thinks that all specialists use the same intellectual tools and are engaged in their specialisms in a process of simplification, so that on both counts cross-fertilisation among specialists and with non-specialists remains possible. Second, he sees a need to increase sharply every individual's output in industry and he thinks this can also be done with a correct mixture of the right kinds of incentive and training. Third, he would seek new measuring rods for effective management, and finally he would have the implications of automation thoroughly and quickly examined without either sensationalism or fear.

It is of interest that he gives the problem of industrial organisation, especially problems of control and communication, great emphasis without under-estimating either the importance of the customer, the profit motive or good production and management techniques. This viewpoint is getting near to that of Professor M. P. Fogarty in his latest book *Economic Control*, in which he emphasises that industry's latest phase of development (and therefore where the problems lie) is not in profits, capitalism and the like, but in consultation.

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A Question of Definition

Great issues may spring from small beginnings, witness the casks of tea once thrown as a prank into Boston harbour. If tea can accomplish so much, what might fish and chips do? The question is not of only academic interest, for Great Yarmouth is faced with the problem of how to dissuade a sizeable portion of its population from eating them on its buses. Damage is reported to have been done to passengers' clothes and a bus conductor has slipped on a chip on the stairs of a bus.

The issue is already building up. The clerk of the town council has intimated that, under instructions to see what can be done (which means that the city fathers have already passed the buck to the bureacratic machine), he is going to consult the appropriate Government department. This immediately raises the matter to a national level where irrevocable precedents can be set. There are bound to be long discussions about the scope of local by-laws and as to what constitutes an offence or a nuisance under them. From these legal complexities will arise the problem as to what is a fish and what is a chip and whether taken together they constitute a third legal entity. The National Federation of Fish Friers has already carried out a flank attack, pointing out that it is the method of eating and not the food which is the issue.

Why should it stop there? Surely the Transport and General Workers Union has a view? It will be a difficult one for them. Are they to favour banning the practice in buses in the interests of the conductor and so accept a prohibition on the driver? Further, hasn't the commercial vehicle industry got an official view on it? When the discussion gets round to grease marks, an important consideration is the width of gangways; criticism might therefore be directed at bus width restrictions. This could go on forever like a chain letter and bring industry to a standstill with a general strike. There is fortunately a chance that either manners at Great Yarmouth will improve or a manufacturer invent a new grease remover before the situation becomes unmanageable.

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Cushion for Redundancy

British industry is beginning to take very seriously the social and management problems that arise when workers have to be sacked. Negotiations between the unions and management in the Midlands are reaching a stage where they might serve as a basis for the framing of national policy. In these cases it is redundancy arising from fluctuations in the volume of work, particularly in the motor vehicle industry and its suppliers of components, but the broader and more permanent question of the replacement of machine operatives by automatic controls is also receiving the attention of even small businesses. A one-day conference on " Automation and the Small Firms," was held last week in Wednesbury, Staffordshire, through the initiative of the Walsall and District Productivity Association. Trade unionists, including shop stewards, and managers were brought together to discuss their common problems when automatic techniques began to spread in an industry. The position of the small firm, generally without adequate resources to provide adequate compensation and re-training facilities, would seem to give rise to some anxiety, although their particular function—supplying the skill and flexibility needed to cater for customer's special requirements—is unlikely to be challenged for some time.

One of the most far-reaching schemes for dealing with redundancy was put out by Birfield Industries, a large and rapidly expanding group of companies supplying the motor industry. They propose to give an extra week's notice for every year of service over two years, up to a maximum of 26 weeks, or wages in lieu of notice. Redundant workers unable to find jobs at the rate of their weekly basic wage would be paid on production of their insurance card; or the company would make up the difference in pay if a lower-paid job is accepted. These proposals, which are still under consideration, go far beyond what has been publicised so far.

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Automation in Germany

Automation was discussed last week at the annual German Trades Union Congress in Hamburg. The leader of the metal workers' union, which has 1·5 million members and is one of the most influential in the country, announced that West German trade unions would welcome automation on two conditions: there must be adequate warning and thorough discussions with the unions; the employers must provide free training and assistance schemes for redundant workers. The " programme of action " of the Congress was similar to many such programmes passed unanimously in this country: a five-day 40 hour week, investment controls, price controls, more paid holidays, six weeks pay in case of sickness. Other points were that atomic energy should be under State control, that there should be strict anti-cartel laws, and incentives for savings.

Although the tone of the meeting was harsh, as if the unions felt stronger than last year, there was no noticeable swing to the left—unless a resolution that the Volkswagen works should remain a State-controlled enterprise could be interpreted as socialism! There is a tendency to go in the same general direction as American trade unions, though much more gradually. These are demands for a reduction of the working week from 48 to 40 hours but the unions realise that this must be gradual.

As a background to labour's demand is a growing threat of inflation. Private consumption is growing faster than the gross national product. The upward movement of costs is threatening to take away at least some of Germany's competitive advantage over the other countries of Western Europe.

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Civil Service Recruitment

Fewer people are coming forward to become civil servants. The downward trend in the number of candidates for the open competitions for the General classes has continued, and the entries for the Administrative and Executive classes show a serious decline. The report of the Civil Service Commissioners for the year ended March 31, 1956, contains other alarming information about the quality of the candidates coming forward. This applies particularly to applicants for engineering and technical posts which the Commissioners have found very difficult to fill.

It is still too early to judge what effect the recent improvement in pay and conditions which became effective last July will have on the recruitment of all grades. There is certainly reason to hope that the large increase in the number of children in the 16 to 18 age groups who will be leaving school from 1958 onwards will result in an all-round improvement in the recruitment for the clerical class.

Perhaps the most alarming trend is the continued fall in the standard of applicants for the Administrative Class, traditionally considered to be the elite and the backbone of the Service. The number who entered the open competition fell by 30 per cent. and the average quality of the candidates was lower, so much so that the Commissioners were able to fill only 31 of the 50 vacancies which had been advertised. A similar situation existed in filling vacancies for the senior branch of the Foreign Office. This is certainly food for thought, and a problem which will require the urgent attention of the Commissioners and of the Government.